Kennelly Notebook #4

This notebook covers the period November 1890-June 1891. It contains transcriptions by Arthur E. Kennelly of material from the rough record books used by experimenters in the Galvanometer Room. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, batteries, induction coils, lightning arresters, and the carrying capacity of copper wire. In addition, there are extensive notes and design drawings relating to electric traction, including motor tests (some of these experiments were conducted at the Edison General Electric works at Schenectady), determinations of the tensile strength of trolley wire, and notes concerning the set-up of the experimental track at the West Orange laboratory. Also included are notes regarding low-horsepower motors and 3- and 5-wire electric power systems, tests comparing Edison's experimental alternators and a.c. motors with those of Westinghouse, and theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are Alfred J. Thompson and Arthur Hoopes. At the end of the book is a subject index (filmed at the beginning of the book). The front cover is marked "IV" and "1890-91." The book contains 170 numbered pages. Some pages were removed before the book was paginated. Numerous graphs, blueprints, tissue copies, and other items have been pasted into the book.

Missing page numbers: 41-44.

Index.

Letter.		Page
A.	Alternating voltages, determination of by Mr Davis	7
	Attraction of Solids in Water, description of exp:	47
	Ammeter, alternating current, for Clinton Prison	112
	Arc lighting test commenced. see heard 91.	113
	Ammeter, comparison of.	118.
	Alternating current, some equations on.	119
	Arc light, motor Edison.	135
	Armature, necessary surface to enable rice delivery of heat	137
	Arc lamp, motor, test of	115 & 116
	Arc lamp, data for new design.	116
B.	Ballistic galvo, data of mounting	10
	Belt, magnetic, electrical measurement of power absorbed by.	32
	Burke's Mill house, pressure taken at.	66.
C.	Clutch, electromagnetic	76
	Copper, power to deposit 15 tons.	87
	Clutch. #2 motor, determination of winding for when in field circuit	96
	Carbon brushes, carrying capacity of	97
	Circular distribution. economical feeding point, Calfor.	98.
	Copper wire, measurement of resistance and dia of from Phoenix works.	113
	Cell. brought by Mr Hamilton from Barnett & Co	158.
D.	Dynamo, marine quadripolar. cal: for design by Mr Sepe	19
	Dynamo, 4 KWT cal: for, design by Eng: Dept, St. G.	20.
	Dynamo, Westinghouse in Sing Sing Prison. Carden observations made by Dr Davis	27
	Dynamo. 4 KWT period cal: for. Const: by Eng Dept St G	58
	Dynamometer, friction, in Machine shop. Apparatus area of	76.

Index (cont)

		page
D.	Dynamo Multipolar, report by Dr Rollen	73
	Dynamo. Alternator, test described on page 38 P III	95
	Dynamical theory of electricity, members of	126
	Dynamo. Edison 400 KWT. multipolar. particulars of	127.
	Dynamo, Alternating, test of at Schenectady	132
	Dynamo. Sperry arc, particulars of.	136.
	Dynamo. 100 KWT @ Schenectady data concerning	139.
	Dynamo. Edison Alternator, result of experiments made 153 & 154	
	Dynamo. Lamp room. speed & pressure. of.	159.
	Dynamo. 110 KWT. Octopolar direct driven data of	166.
	Dynamo. Alternator exp: with	168.
E.	Electro Kinetic momentum. permissable amount loss measurement of in circuits. terminals & commutator	4.
	Edison. Lalande. - test of 3 - 600 Amp Hour cells. in series. working Phonograph	5
	Electro magnetic circuits, and condensers interchange relation & exp: between	22.
	Electro action calibration of alternating current ammeter for Sing Sing	37
	Electro Deposition of Ag. Chr. K. Cn. Solutions	76.
	Eddy Currents. energy lost in Armature of Dynamo.	104
	Edison Station 26th Street, record made on fall of pressure	115
	Edison Lalande - double cells in porcelain jar	124
	Edison Lalande telephone cells. 2nd & 6 April	125
	Evaporation Experiment	125
	Edison Lalande cells. local action in an open circuit	129.
F.	Fuses. lead foil. delicate measurement of between wires	6.
	Free impact in simple masses, connected with their elastic modulii, mathematical laws &c.	54
	Fan. Bingham. power taken by Hardie	60.
	Frictional Resistance of Vulcanized rubber to motion over its surface	82.

Index

Lett.	Iron wire Edison System. Standard determinant for.	Pages 95
H.	Elementary rectangle. Induction in	122
	Heroes Brooklyn. Tests of	159
G.	Herman Felix. resistivity of Carbons	89
	Herman Felix Wire. braiding & increase carrying capacity of	104
	Herman Felix. Constance & carry 200 Amps.	136.
A.	Hydrothermal case System. operation of dates: of conductors size & weight	14
H.	Human Being, activity of average	35
I.	Inductance, measurement of millihenry & Ampere meter	15
	Induction coil, data relating to experimental	16
	Induction coil, medical, data of operated by Edison Lalande cells.	18.
	Induction coil, large, inductance of secondary	27
	Inductance, in large Edison Field magnet	27
	Inductance, table of copper wires suspended marked	29
	Iron soft, Ring, marked from Eng Dept.	105
	Iron hard. " " " " "	107
	Iron Wire Heating of in resistance boxes. data for.	147
L.	Lightning protection, committee meeting	119
	Lightning arrestors for Edison Illum: Co.	135
	" " " " " Statistics	142
	Lee Fuller cells. test of	
M.	Motor Phonograph dia for coils of field magnets	1
	Motor ½ HP Edison New. 1st test included: magnetic test	11
	Motor Edison small second test	21
	Motor " " efficiency test of with Field cast Iron.	
	Same Model as page 21	

Index (Cont)

Lett.	Motor Gramme Ring formulae for armature breaths.	page 32
	Motor 100 WT Edison Electromagnetic design	35
	Motor ½ HP magnetic measurements of	26.
	Motor ½ HP particulars of by various manufacturers	28.
	Motor ½ HP Final test of before sending to New York	29.
	Motor. Small Dynamo. classification of as arranged with Mr Anderson	38.
	Motor Pacinotti both armature & Ring type breath of grooves in	39.
	Motor 500 Volt. particulars for winding	40.
	Motors 100 Volt ½ HP Test of	46.
	Motor 100 WT Model. analysis of function loads 1, 2, 3, 4th and 5th Tests	48.
	Motors. Dimensions of Tank & float. 400 lbs.	50.
	Motor 100 WT. length and size of wire needed for Dynamo.	50.
	Motor ¾ HP Britis Dyn. Test of.	51
	Motor ⅛ HP Test of after laminating pole pieces	55
	Motor ½ HP. Calculations winding for. 220 or 500 volts	57.
	Motor ⅙ HP reduced to 60 volts pressure design of	58.
	Motor ⅛ HP after tapering both pole pieces, test of	59.
	Motor ⅛ HP after slopping poles both sides	61.
	Motor Resume of Dimensions of small	62.
	Motor ¼ HP electromagnetic design of for 120 V	63
	Motor particulars concerning small motor by different firms	64
	Motor Parent. test of 1 HP	67
	Motor C+C. test of ½ HP	70.
	Motor ⅛ + 1/10 HP best designs of connecting platinoid wire	71.
	Motor 1 HP. Wrot wrought Iron fields & 500 voltammeter	77
	Motor 100 WT. British Iron fields, with smaller platinoid & pure tube	80.

Letter		Page
C.M.	Motor ¼ H.P. after second changing to 97 wire	82.
	Motor ¼ H.P. Magnetic circuit test of	86.
	Motor 1 H.P. 120 volt. First test of	87
	" " " Second " "	87.
	" " " Test "	88.
	Motor ½ H.P. First test of	89
	Motor 50 Volt. Test of	90
	Motor ¼ H.P. Test of.	91
	Motor ¼ H.P. Test of, through library model	92
	Motor ¼ H.P. Determination of series field winding	93
	Motor ½ H.P. Efficiency test of after filling with solid pole pieces	93
	Motor ½ H.P. Final test of.	94
	Motor Perot. Trial of for Edison, Lalande Battery	99
	Motor ½ H.P. Magnetic test of	99
	Motor ½ H.P. Winding for @ 250 volts.	101
	Motor ½ H.P. Test of with solid pole pieces	102
	Motor " " 2nd " " " " " on 50 volt circ. after filling with larger pt. wire	102
	Motor ½ H.P. Efficiency test of before going to New York	108.
	Motor ½ H.P. 500. Crocker. Wheeler.	111.
	Motor 1 H.P. Shunt Field Winding	118.
	Motor ½ H.P. 250 Volt. test of Series wound	120.
	Motor 1 H.P. 120 volt test of	121
	" " " " " Separate Excitation	121
	Motor 2½ H.P. best dimensions for.	123
	Motor Multipolar formulae for data of	130A
	Motor Multipolar Gramme Ring Data of	130
	Motor 1 H.P. Specification for.	131.

Letter		Page
C.M.	Motor 2½ H.P. calculation for.	138.
	Motor, operating of. conclusions arrived at.	140.
	Motor, two Leland fan, test of on L. Lalande cells	148.
	Motor, Lieb. test of before winding for battery fan work.	157
	Motor 1 H.P. 500 volt winding for.	162
	Motor. fan. electromagnetic circuits data: of for 120 volts	167
	Molecular. principle. some facts in arranged for comparison	145
	Meteorological Records.	72.
	Meteorological Observations summary of @ C.K.G.	74
	Motor, Edison, Electrolytic, new.	75
	Motor Pottsville First test of for L. C. & C.	150
	Motor Walker. Test of scale	162
	Motor Edison electrolytic, data, concerning new.	164
	Motor Pottsville, test of on load	165
	Machine design for driving simultaneous linear parts	170
C.	Clock Pulse. constant determination of.	2
	" " " " "	66
	" " " & Standard "	66
	" " " "	78.
	" " " "	163
	Ore Separating with C. Ogden apparatus reg for	13
	Ore Drilling analyzer magnet for Mr Batchelor with Data	31
	Ore Drilling magnets. Dimensions of 16. winding for.	149
P.	Permanent magnet. experiment with	30.
	Phonograph battery. electrical data of New Model	31
	Phonograph. Electromagnetic lift. Dimensions of wire reg:	45
	Platinoid, resistivity of Brown by M. M. gauge	93
	Permeance magnetic of a soft steel Ring from Sohn:	103
	Permeability magnetic standard, wooden Ring, Dimensions for	110

Page

H. Ring Tangent, and cross wire Division Calc constant. 71
" " Const of after readjusting 78
Negative Arrangin, determination of Commutator relations of 155
Resistance Standard for measurement in Underground Sys 158
Resistance Standard, comparison of 160
Resistance Standard, test of in terms of 1" Copy Station 163
Resist Magnetic test particulars of received from 164
Ring #1 Test of. 164
S Street Car Motor for armature, test of. 3
" " Rheostat, description and data of 8
" " Experiments made @ Schenectady 9 & 10
" " Experimental pulley, test winding for. 17
" " Magnetic Pulley. #3 power of 23
" " " " 8" weighing motive 23
" " " #2 power in permanent magnets 28
Sh " Motor 25 H.P. calculations concerning (Blue print) 38.
" " Sprocket Chain, upon rubber covered pulley 47
" " Motor, Sprague. from page 39. 52
" " " 25 H.P. determination of winding exp. 38 & 52-56
" " Edison #2 Switchboard wiring, cal. of. 60.
" " " " #2 Lamp resistances in field circuit 65
" " Sprocket chain, determine power necessary 65
" " " " Belt. on Experimental track 78.
" " Catenary pressure on axles 79
" " Report by Mr Krouse, pull required to start on level rails 79.
" " Chain friction of coefficients relating to 81.

Index (Cont)

S. Street Car Motor #2 experimental 94.
" " " #2 In new fields 96
Street railroad, data concerning 97
Street Car Motor #2 magnetic test of 108.
" " Track. test: resistance of. 135.
" " System Low Tension Max 20 K hrs 15 164
" " Motor 6 by 9 grade. Data: of winding for Fields 150.
" " " " " Participation in Sect Cont Stat 142
" " " " " Sect on armature pole tips 144
Safety Conduit tubes test of. 14
Silver Chloride cells, test & Data of. 29.
Switches, carrying capacity of six on Porcelain base 65
Specific Gravity of Sample of Aluminum, German Silver, Steel 71
Safety cut out. high tension, test of. 88.
Search coil Data of. 90.
Nest cast Ring makes, from Eng Dept. 106
" " " " Repetition of 107.
Switches, carrying capacity of 124
Street magnetic test of Sample of Gen. Steel Co. #1 152
Setin - Ethylamine, injected into arterial system of a patient 20.
Trolley wire, hard drawn copper, from Eng Dept 35 & 36
Tension & wire System. Cal. for drop in conductors of 49.
Tank. particulars for floating motor 68.
Telephonic Induction, between two wires, a problem in 109.
Telephonic Experiment 112.
Taylor battery, test of two cells. 114
Telephonic Experiment. ~~test~~ 116 & 117.
Trolley Wire Silicon Bronze. made @ Bronlee N.J. 128 & 129.

Page

G. Trans position formulae, best values for our Constant 151

Spelling Tree. Edison Bonus from Eng Dept. 161.

I. Fall meter. Edison Gravity Data of 50

Velocities. table of 84.

H. Weidermann System determination of copper for size & weight 12

Wire table, data for compilation 69

Weiderman Thermo Balance Coil & Resistance of 88

Watt Meter. Thompson Houston. test of 133

E5931-4

No. IV.

Record Book

of

Observations, Calculations, and Data

compiled in the Galvanometer Building

Edison Laboratory, Orange N.J.

commenced 3rd November 1890
completed 7th June 1891.

On the most suitable diameter for the cores of the phonograph motor's field-magnets. 3rd November 1890.

From measurements made on 3rd Sept: 1889 vide Book II. p. 44, a sample phonograph motor making 7.33 revs: per second generated 1.485 volts or 0.2026 volt per rev: per sec. The number of wires counted all round is 1080

$$\therefore \varphi = \frac{2.026 \times 10^7}{1.08 \times 10^3} = 1.876 \times 10^4 -$$

The exciting cross section of core being 24 sq. cms, the induction density is $187.6/24 \times 10^2 = 780$. say 1000 allowing leakage

(1) If the iron be of the usual casting material, an induction density of 3000 may be readily granted, or allowing as above for 22% leakage 2340 for useful flux. The cross section should therefore be 8 sq. cms. = 3.2 cms or 1.26" say 1¼" diameter.

(2) If the iron be mitis casting, then double this density may be used, the cross-section need only be 4 sq. cms. = 2.26 cm = 0.9" diam.

The winding for (1) of the same power will have as at present 135 turns to have 0.460 ω. The mean circumference being say 1.5" × 3.142 = 3.71". = 0.31' 135 turns = 41.9'. (The present length is 105'). This is equivalent to 0.46/41.9 or 0.011 ω per foot. The nearest size to this is # 21 B.W.G. 0.0101 ω per foot or 45' for 0.46 ω.

The new winding will therefore be

45' of # 21 B.W.G. per limb = 0.46 ω
180' - - - - - field = 1.84 ω

To give the same exciting power with the existing weight of copper, which is 420 × 0.007268 = 3.05 lbs. on the field or 0.76 lb: per one: we have to use a wire ~~#22~~ ' long weighing 0.76 lbs and of $\frac{42}{105} \times 2401$ cmil = 960 = # 21 B.W.G. = 3.253 ω per lb = $\frac{2.47}{3.253}$ ω per limb = 250' = 700 turns.

With # 19 B.W.G. whose res: is 1.096 ω per lb: there will be with 12 oz 0.82 ω on each limb or 3.28 ω for all. The length being 184' per lb. there will be 140' or about 450 turns. Hence with $\frac{450}{135}$, 3.33 times as many turns there will be 1.75 times as much resistance reducing the battery current about 40%.

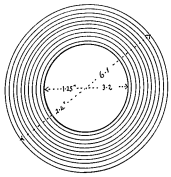
With #20 B.W.G. whose res: is 2.27 ω per lb. the res: of 12 oz = 1.7 ω or 6.8 ω for the total field or 3.7 times as much as at present. The length will be 200' per limb = 670 turns = 5 times as many turns. The total gain in exciting power should thus be $\frac{5}{3.7}$ = 1.4.

The diameter of the wire = 0.032" or covered 0.042. There will be 40 turns per layer and 17 layers. Mean diam 1.25 + 7(0.042) = 1.95" = 6.25' = 0.5' = 400 turns = 10 layers

Mean diam 1.25 + 0.42 = 1.67 = 5.25' = 0.44'

Full size cross section of modified field limit phonograph magnet.

Cast iron



Cross Section of core 8 sq. cms.
Diameter 1·25" 3·2
Ext: diam 2·4" 6·1
Total flux 18.760 useful
Total estimated flux 22.000
Induction density 2.750.
Resistance of limb 0·82ω
Current in field with 2·2 volts at mt. 0·67 amp.
M.M.F. on one limit 250 A.T. per limit 192, per pair 384.
Weight of wire on each limit 12g (340g). Total weight of wire 3lbs (1360g)

Diameter of wire 0·042" #19 S.W.G.
– covered 0·057"
Turns per layer 31
Number of layers 9.5
Depth of winding 0·58" 1·45
Total turns 288.
Resistance of field 3·28ω.

Test 10th turn: 91 of a specimen field, first one wound to new model at Phonograph Works 0·042" wire cov'd 0·056"
8 layers of 36 turns each on each limit
Res: 0·77ω per limit or 3·05ω in all.

The best result will be given by #19 S.W.G. whose diam: is 0·042" or 0·057" any covered = 31 turns per layer, and with 12 layers, the mean diam: = 1·25 + 0·69 = 1·93" = 6·07 circ: = 0·505' and 144·0' = 279 turns = 9 layers. The mean turn π(1·25 + 0·51) = 5·53" = 0·46' = 300 turns = 10 layers. 0·57" diaf. Mean turn π(1·25 + 0·57) = 5·92" = 0·485' = 288 turns = 9·5 layers. There will then be 2·13 times as many turns as in the existing apparatus, and 1·75 times as much resistance, a gain of 1·28 or 28% in exciting power.

Determination of the Obach Galvanometer Single Ring Constants by electrolysis: 31st October 90. Observer A. J. Frazer.

The following are the results of a series of observations with two voltameters. One using silver electrodes in a 25% solution of $AgNO_3$, the other copper electrodes in $CuSO_4$ solution.

No. of Obs.	Voltameter	Weight of plates before test	Weight of plates after test	Transfer	Accepted transfer	Time duration of test, sec.	Transfer per second	Constant for Ag & simplified	Current	Mean Deflection observed	Constant per amp.
1	Ag:	11·7470 11·8216	11·8146 12·5244	0·7024– 0·7028+	0·7026	300	0·002342	0·001118	2·09144	0·4018	0·1918
2	Ag:	10·9646 11·8239	11·5948 11·1940	0·6302+ 0·6299–	0·63015	300	0·0021005	"	1·8785	0·36158	0·1925
3	Cu:	17·0838 17·5000	16·8797 17·7037	0·2041– 0·2037+	0·2039	300	0·0006796	0·0002279	2·07297	0·39639	0·1912
4	Cu:	16·8797 17·7037	16·4500 16·1362	0·4297– 0·4325+	0·4297	600	0·0007160	"	2·18410	0·41558	0·1903

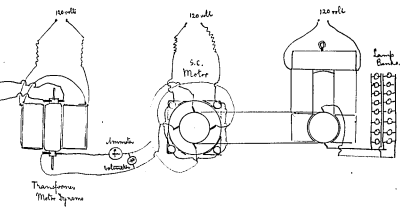
Reduction of these values 0·1917 ± 0·000024

No.	Mean Ag. value	Weight.	Mean Cu value	Weight.	General Mean		v	v^2	βv^2	$\Sigma \beta v^2$	v_0
1	0·1918	(3)			90		0·0001	1×10^{-8}	5×10^{-8}		
2	0·1925	(3)			75	0·19170	0·0008	64×10^{-8}	192×10^{-8}		
3			0·1912	(3)	36		0·0005	25×10^{-8}	225×10^{-8}	466×10^{-8}	0·000024
4			0·1903	(1)	3		0·0014	196×10^{-8}	196×10^{-8}		

During the last test the Trow ring deflection was observed as follows

	Voltameter								Current	Deflection	Constant per amp.
4	Cu:								2·1811	16°25' 0·2846 rad	Tan: 0·1349 per amp

If this current be reduced to the general mean = 0·1359 per amp. tan. 7°.45'.



Test of the 20 volt quadripolar, bar-armatured Street Car Motor, whose design is recorded on page 72/73 Book III

The following observations were made with the field magnets all connected in series, and ~~also~~ excited with different current strengths.

No. of Obs.	Current in field.	Revs: per min:	Revs: per sec:	P.D. at m.t.	Revs per min: reduced to 15 volts emf.	Revs: per sec: reduced to 15 volt emf	Peripheral Speed in kins @ 15 volts emf	
1	4·5	940	15·67	20	720	12·0	1914	On 2nd occasion
2	8·0	810	13·5	21·5	565	9·42	1503	On 1st occasion
3	10·0	524	8·73	21·0	374	6·23	994	- - -
4	5·0	1200	20·0	21·5	837	13·95	2225	- - -

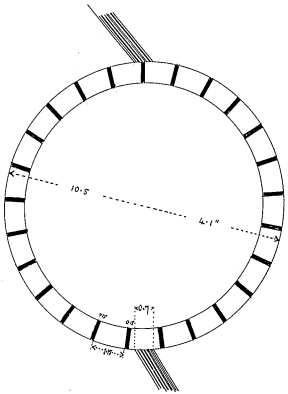
The peripheral speed designed for was 2500 kins at 3 amp: in the field at 15·7 revs: per sec. The actual speed is reckoned by the above to be at 3 amp. 2870 kins at 18 revs: per sec. In other words the reluctance of the circuit is 1·146 times its estimated amount.

The next observations were made with a load on the motor. It was noticed that the machine heated considerably when operated without load in a strong field. The temp: on the armature rose to 130°F after a run of one hour and to 175°F after a run of three hours in ~~a~~ 9-amp. current field. This was principally due to the foucault currents generated in the armature shell or commutator bars of brass when the armature became nearly saturated. With a higher speed, and weaker field, the heat generated was distinctly less and took place principally in the bar themselves. They are evidently sufficiently wide to permit strong eddy currents.

No of Obs	Current in field.	Current in motor	P.D. on motor	Energy in motor	Samples operated by dynamo	Current per amp estimated	Energy in dynamo est.	Energy delivered @ 86·7	Speed of motor revs: p. m.		
1	4·5	70	20	1500	not belted						
2	4·5	175	20	3500	belted				940		
3	4·5	480	16·4	7870	166	0·4	6640	7720	720		
4	4·5	520	16·45	8555	180	0·4	7200	8370	700		

This efficiency estimate is ~~only~~ very rough because the current and emf in the dynamo circuit were not observed.

Full size section of commutator at right angles to its axis



Measurement of the permissable amount of electro-kinetic momentum, in the circuits terminating at commutator bars.

A commutator of 100 bars, and of dimension represented, had its bars connected together in four, so as to make in effect a commutator of 25 bars. This commutator was fixed with its axis horizontal and projecting from a wooden frame holding 25 ring transformers of the pattern whose complete tests are recorded on p. 150 Book III. The bars were connected to the coarse wire coils of these transformers, arranged in continuous series, like a gramme ring. The fine wire coils were connected to a similar commutator with a separate pair of brushes. The measurements were made first with one and then with the other commutator with varying currents and speeds, simply to determine the limiting degree of sparking that could be permitted and the conditions of electrokinetic momentum calculated to be existing at the moment of breaking each coil circuit at the brush.

If n be the no. of revs. of the brushholder per sec, and r the radius of the commutator the peripheral speed will be $2\pi nr$ nearly, and since the brush face is 0.7 and the insulation 0.15 the time of short circuiting will be $0.55/2\pi nr$.

Fine wire commutator

No. of Obs.	Current in machine	Current in each coil	Inductance of each coil	Time constant of each coil	Speed of brushholder per min.	Revs. per second n	Peripheral Speed $2\pi nr$	Time of Short-circuit seconds	$C\,\varepsilon - \frac{f}{\text{Inductance}}$ current c_1	$c_1 - c_2$	$L(c_1 - c_2)$ volt-seconds	Spark
1	1.1	0.55	0.01463	0.01308	740	12.33	406.8	0.00135	0.495	1.045	0.0684	moderate
2	1.7	0.85			390	6.5	214.5	0.002565	0.70	1.55	0.07176	bad
3	1.0	0.5			880	14.7	485.0	0.001314	0.46	0.96	0.0446	medium
4	1.2	0.6			675	11.25	371.1	0.001483	0.536	1.136	0.0526	[illegible]

The observations were then repeated on the coarse wire commutator as follows:-

No. of Obs.	Current in machine	Current in each coil	Inductance of each coil	Time constant of each coil	Speed of brushholder per min.	Number revs. per sec.	Peripheral Speed $2\pi nr$	Time of Short ckt. seconds	$C\,\varepsilon - \frac{f}{\text{Inductance}}$ current c_1	$c_1 - c_2$	$L(c_1 - c_2)$ volt-seconds	Spark
1	5.5	2.75	0.001806	0.014480	960	16.0	527.9	0.001016	2.566	5.316	0.009604	just bluish
2	6.8	3.4			660	11.0	363.	0.001515	3.06	6.46	0.01167	— " —
3	8.3	4.15			468	7.8	257.4	0.002138	3.577	7.727	0.01396	— " —
4	9.7	4.85			400	6.67	220.1	0.00250	4.110	8.960	0.01619	— " —
5	0.9	0.45			780	13.0	428.9	0.001283	0.413	0.863	0.01556	barely perceptible
6	2.0	1.0			360	6.0	198	0.002778	0.829	1.829	0.00330	— " —

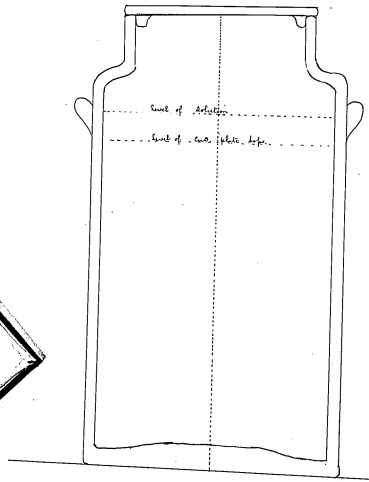
The maximum permissable momentum or impulse for the coarse wire coils was 526 kilometre amperes or $\frac{1}{20}$ lb volt-second, apparently independent of the speed, for the coarse wire coils it was 160 kilometre amperes, apparently diminishing with speed

Mechanical Data of Cell.

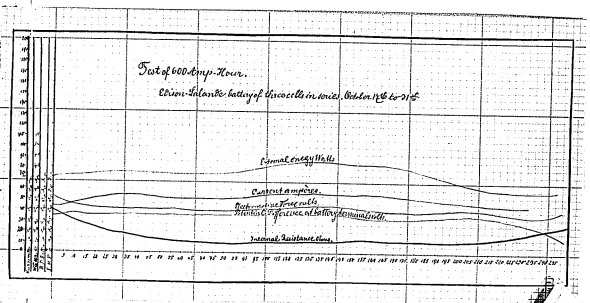
External space occupied when charged & set up 21·14 X 20 X 38 high
8 1/2" X 8" X 15" "
volume - - - - - 1626 c.c.
99·2 c.in.

Weight of cell (stone ware jar)		8 lbs.	6 1/2 oz.	3813 gms.
Volume of liquid contents.	5500 c.c.			
Weight of " " @ 1·25 =	6875 gms	15	2 1/2 "	6875
" " two zinc plates	792 gms	1	12 "	792
" " " copper oxide plates in wire frame		2	0 "	907
" " one copper frame.			5 1/2 "	156
" " porcelain cover			10 "	284
" " Total weight charged		28 · 4 1/2 .		12827

Area occupied by each charged cell 68 sq. in. 438 sq. cms



Vertical section of 600 amp. hr. jar through the axis 1/2



Test of 3 Edison Lalande 600-Amp: hour cells joined up in series and working a phonograph. from October 17th to October 31st 1820.

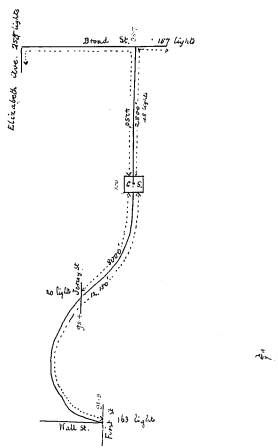
Date	Time	Hours Hrs. mins	E.M.F.	P.D. battery	P.D. motor	Clock	current	Phonograph Speed Revs. per min.	Watts
17th Oct.	13·35	0	2·676	1·838		0·428	2·14	145	3·9
	18·05	4·30		1·802		0·400	2·00		3·6
18th	8·05	4·30		1·790		0·47	2·37		4·24
	11·20	7·45		~~1·774~~	1·774	0·43	2·20	142	3·3
19th	17·05	12·30			1·774	0·43	2·2	142	3·9
20th	8·10	17·30			1·746	0·444	2·2		3·8
	12·00	22·20			1·684	0·53	2·7		4·5
21st	8·30	37·50	2·116	1·824		0·47	2·35		4·3
22nd	9·15	62·35		1·806		0·47	2·35	140	4·2
23rd	8·35	85·55		1·810		0·50	2·5	0	4·5
	11·25	88·45		1·818		0·43	2·15	130	3·9
	17·00	94·20		1·850		0·43	2·15		4·0
24th	8·15	109·35		1·840		0·49	2·45	130	4·4
	12·00	113·20			1·774	0·575	2·88		5·1
25th	8·30	133·55	2·132	1·756		0·445	2·23	134	3·9
	13·30	138·55		1·732		0·5	2·5		4·3
	17·45	143·05		1·782		0·437	2·18		3·9
27th	8·30	143·05	2·084	1·752	1·590	0·520	2·60	144	4·5
	13·30	148·05		1·700		0·51	2·55	142	4·3
	18·00	152·35		1·750		0·47	2·35	136	4·1
28th	8·30	167·05	2·060	1·730	1·670	0·45	2·25	148	3·9
	18·00	176·35		1·782		0·39	1·95		3·4
29th	9·00	191·35	1·952	1·706	1·652	0·38	1·9	150	3·2
	17·15	199·50		1·706	1·654	0·39	1·95		3·2
30th	8·30	215·05	1·924	1·506	1·462	0·41	2·05		3·1
	17·50	224·25		1·578	1·528	0·36	1·8	126	2·8
31	8·30	239·05	1·626	1·044	0·912	0·585	2·92	0	3·0
	12·30	243·05							
	16·30	243·35	1·452	1·004		0·42	2·1	90	2·1

The battery thus operated the phonograph about 10 days in all. Chipping was occasionally practised also to imitate actual service, but probably the work done in chipping with practically worked instruments would exceed that here given, so that 10 days would be an outside limit. The sp. g. of the solution before starting was 1·225 and at close 1·36. One zinc had actually been consumed till it broke near the surface. The weight of zinc in the battery at ~~start~~ was 40 @ 1160 grs. or 120g gms and ~~close~~ was 66 @ 1372 - 1960 -

~~Loss 26 212 - 751~~

Starting Weight of Zinc	Closing Weight of Zinc	Loss	Mean Current	Amp. Hrs.	Calculated Loss	Discrepancy
316g	120g	1960	2·25	2·26 × 243·5 = 550·3	8 × 67·6 = 2020·8	60·8 gms.

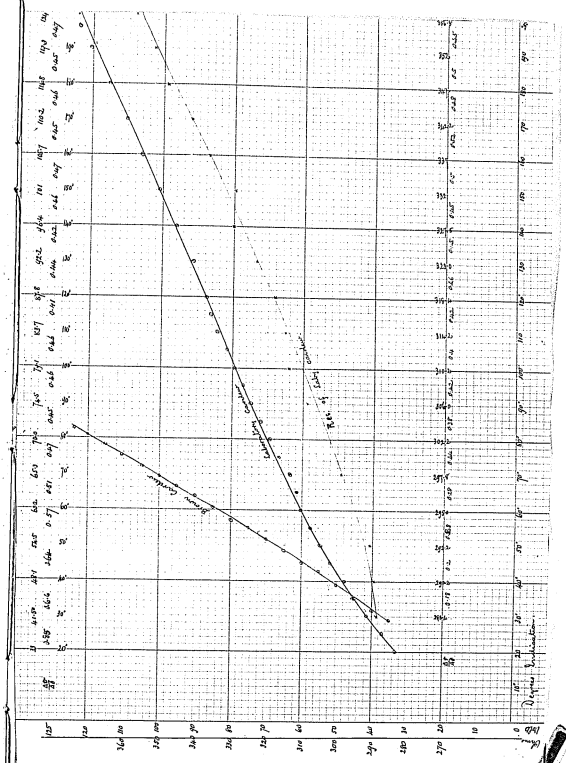
Measurements made with delicate fuses of lead foil strip between mica sheets. Nov. 90.



163	lights	operated	at 1st & Wall St	a distance of	12,150'
20	-	-	- Jersey St	- - -	8000'
187	-	-	- Broad St	- - -	2800'
255	-	-	- Elizabeth Ave	- - -	2800'
48	-	-	- Feeder to Broad	- - -	4250'
643	-	-	- on two feeders.		

Ammeter indicates over 35 amperes

Size of feeder 0.200" #6 B.W.G. = 2.5×10^{-4} ohms per foot.



Determination of Alternating Voltages by Mr Davis at the Central Station, and different points of the conductor system in N.S. 5th + 6th Nov. 1820.

Laboratory Gardner Voltmeter

Res. of inst 288 warm

Degrees Incl.	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°	180°	190°	200°
Continuous volts	33·2	41·6	47·8	54·3	60·1	63·8	69·2	74·5	79·4	84·5	87·6	91·6	96·0	101·0	106·1	110·3	115	120·6	124·4
ΔV	8·4	6·2	6·5	5·8	3·7	5·4	5·3	4·9	5·1	3·1	4·0	4·4	5·0	5·0	4·2	4·8	5·6	3·4	
$\Delta V/\Delta\theta$	0·84	0·62	0·65	0·58	0·37	0·54	0·53	0·49	0·51	0·31	0·40	0·44	0·50	0·50	0·42	0·48	0·56	0·34	
Current Kas	9·5·0	10·30	12·0	13·30	14·30	15·70	16·0	17·10	18	19·0	19·30	20·0	20·30	21·30	22·0	22·30	23	23·30	24
Res.	0·0729	0·0570	0·0399	0·0365	0·0259	0·0294	0·0250	0·0247	0·0242	0·0243	0·0203	0·0197	0·0199	0·0197	0·0192	0·0192	0·0192	0·0189	0·0183
	0·0293	0·0323	0·0375	0·0395	0·0323	0·0370	0·0366	0·0391	0·0416	0·0457	0·0467	0·0508	0·0502	0·0507	0·0522	0·0522	0·0522	0·0529	0·0547
	0·0123	0·0143	0·0163	0·0160	0·0202	0·0213	0·0231	0·0246	0·0259	0·0279	0·0297	0·0318	0·0329	0·0329	0·0343	0·0343	0·0343	0·0343	0·0363
	164·7	188·6	224·2	250·7	324·7	320·9	310·3	309·4	310·1	310·3	318	322·6	330·6	339·6	337·3	340·5	342·3	342·6	365

Brown Gardner Voltmeter

Calibrated 28th October 1820.

Volts (continuous)	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110·5	115	120	124
Degrees rotation indicated θ	29	31·8	35·6	38·8	42·6	45·2	48·3	51·9	55·0	57·5	60·5	63·8	66·7	69·4	72·0	75·1	78·0	80·8	82·5
$\Delta\theta$	2·8	3·2	3·8	3·8	2·6	3·1	3·6	3·1	2·5	3·0	3·3	2·9	2·7	2·6	3·1	2·9	2·8	1·7	
$\Delta\theta / \Delta V$	0·56	0·64	0·76	0·76	0·52	0·62	0·72	0·62	0·50	0·60	0·66	0·58	0·54	0·52	0·62	0·58	0·56	0·34	
$\Delta V / \Delta\theta$	1·76	1·56	1·32	1·32	1·95	1·61	1·39	1·61	2·0	1·67	1·52	1·72	1·85	1·92	1·61	1·72	1·79	2·94	

Res. of instrument warm 3574 Add 10% see Book II. p.102 = 383 5m 72°
1st coil 10714 13·28 380 - 50°
2nd coil 4291 5649 378 - 44
3rd coil 7026 12645

Mr Davis' Observations.

Date	Position	Reading	Resistance	Multiplying power	Volts	Reading	Res. in ct	Multiplying power	Volts		
		H.P.S. Gardner				Brown Gardner					
Nov. 5th	C.S.	44°	7500	29.000	57·8	1214	35	7500	450	289·3	1212
		45°	7000	29.670	59·6	1178	38	7000	47·4	291·7	1201
		50°	6000	26.79	64·4	1172	54	6000	56·9	292·8	1223
6th	C.S.	72°	4000	18·28	105	1850	121	4000	88·2	318·9	1350
		43·5°	7500	29.000	56·7	1191	33	7500	43·7	284·3	1194
		45°	7000	29.670	59·4	1173	37	7000	46·5	289·5	1171
		51°	6000	26.79	64·7	1154	47	6000	55·9	291·6	1142
		72°	4000	18·280	105	1895	118	4000	87	317·6	1183
Jersey	Jersey St	43°	7500	29.000	55·7	1177	33·5	7500	43·8	285	1197
		44°	7000	29.670	57·8	1137	38	7000	46·9	289·8	1175
		48·5°	6000	26.79	60·3	1097	52·5	6000	51·5	290·3	1188
		47·5°	4000	18·28	96·5	1089	113·5	4000	85·1	315·8	1163
10th	1st Walk	48·5	7500	29.000	52·3	1095	30	7500	41·5	285·4	1201
		42	7000	29.67	50·2	1066	34	7000	46·1	289·2	1112
		45·5	6000	26.79	60·5	1066	43	6000	50·0	290·8	1082
		62	4000	18·28	97·5	987	100	4000	78·1	310·2	1101
	Euro Plank	42·5	7500	29.000	52·9	1153	35	7500	40·5	289·3	1206·5
		44	7000	29.67	57·9	1137	38	7000	44·9	289·8	1177
		49	6000	26.79	66·0	1105	49	6000	53·9	292·0	1162
		68·5	4000	18·28	98·4	1111					
	Broad	43·5	7500	29.000	56·6	1159	35	7500	44·9	289·3	1207
		44·5	7000	29.67	58·9	1157	38	7000	46·5	289·9	1177
		49·5	6000	26.79	66·7	1120	51	6000	55·9	292·5	1186
		68·5	4000	18·28	98·6	1111	111	4000	84·1	314·6	1154

(1) (2)
1175 1200
1192

1175 1174
1175 = 100

1115 1175
1156 = 98·3

1036 1102
1080 = 91·9

1124 1178
1160 = 98·7

1138 1173
1161 = 98·7

Description and Data of an Eickemeyer Street Car and Motor, from a report by Mr. J. H. Vail to the Engineer-in-chief dated 8th Nov. 90.

Motor Series wound bipolar drum armature Eickemeyer winding
Speed 100 revs to 180 revs: per min 1.67 to 3 revs. per second
peripheral speed 314 to 565 ft per min = 5.25 to 9.4 ft per sec
Velocity ratio of armature to car axle ~~[illegible]~~ 1, and speed of car = 0.0536 n miles per hr. where n = revs per min
Number of sections in armature 70, each of 8 turns. Wire = 560
Breadth of drum 17" diam: of drum 12" (core measurement)
Cross section of core 204 sq. in (1316 sq. cm.)
Wire #9 B&S 0.114". Res: between brushes 0.7Ω. 2 layers.
E.M.F. of supply 250 volts. Power 15 HP = 11,300 Watts. Current 45 amp
Density of current 600 amp per sq. in.
Maximum useful flux $2420 \times 10^6 / 1.67 \times 560$ = 25,660,000
Density of flux in ~~[illegible]~~ body including insulation space 19,500 ?
Field coils consist of 900 turns of #8 B&S 0.1285" in 2 sections
Resistance 4.0Ω = 64.00' = 7.1' per turn? . When sections in multiple res: of field = 1Ω.

The motor shaft is connected at each end to crank discs through universal joints. Crank pin radii in these disks make angle of 90° with each other. Pin radius = 4". Connection is made directly from these disks to the car wheels 18" in diam: by connecting rods 17' long. Both crank and wrist pins have ball bearings.

The weight of the car on which this motor was placed was as follows:- Motor 2400 lbs.
Truck 3470 .
Carbody 1700 . 7570
8 persons 1130 8700

The car was very short and carried one motor. The track was about ¼ mile long, practically level except one short grade of 3%, and was straight with exception of one curve of about 50' rad: also on a slight grade. The day was wet, the rails clean and moist. There was one trolley wire, and the rail return was used. Drop in conductors about 5 volts. The following readings were taken at 10 second intervals.

					Speed							Speed						
					4 miles							4 miles			level	4 miles		Grade
No: of Obs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Volts	250	220	220	210	220	220	220	220	210	200	210	210	260	250	240	220	210	200	240
Amperes	35	25	20	20	20	22	25	25	25	25	20	40	35	25	15	15	20	20	22
Watts	8750	5500	4400	4200	4400	4840	5500	5500	5250	5000	4200	8400	9100	6250	3600	3300	4200	4000	5280
Watts Joules	87500	142,500	186,900	215,600	179,400	232,900	278,900	318,900	423,400	473,400	556,400	638,400	746,400	833,900	878,900	912,900	956,900	996,900	1061,700

Power estimated to be wasted in armature 425 Watts = 252,000 Joules
" " field 900 " .

Haulage @ 25 lbs. per ton = 8,450 ft lbs = 115,000 Joules
Lift @ 20 feet = 174,000 " " = 232,000 "
Acceleration to 7.5 mph = 22,000 "
Estimated Total useful work done 369,000
Power absorbed 1,027,700 Joules, developed in armature 772,700 = 75 %
" usefully 369,000 = 36 %

Record of Experiments made at Schenectady Works 10th – 16th November 1890.

On arrival at Schenectady 10th Nov. the experimental car with motor #1 (128 dia: armt) and two 5" magnetic link belts was taken out on the track. It ran successfully on the level, but generally stopped on the 5% grade, the belt then slipping on the small pulley. The p.d. at car was about 500 volts and the current about 8 amperes. The weight of the car complete was 10,950 lbs or with 4 men 11,200 say = 5.75 tons. The limiting pull on the two belts together was therefore 5/100 × 11,500 = 575 lbs. with 50×8 = 400 ampere-turns in each small pulley. On one occasion however the car succeeded in mounting the grade (see Book III p. 123).

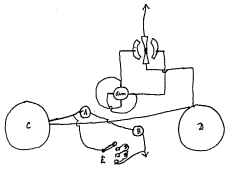
In a subsequent trial armature #1 abraided the polar heads, and became badly damaged. It was taken out and replaced by armature #2. (128 dia) radially connected with 4 brushes of carbon.

The belts did not make more than bare contacts with the surfaces of the small pulleys. To increase the surfaces in contact, they were ground on an emery wheel to the contour of the small pulley. An experiment was then made to ascertain the effect of this upon the traction. With 800 ampere turns in one pulley, the increase of traction was about 20% with the ground links over the flat links in belt.

The car was again tried on the track with the #2 armature and the ground belts. On this occasion there was a greater pull at the small pulleys, but the belts now slipped on the large pulleys. This was traced to bad grounds in each large pulley and one clutch. The car was therefore taken back to the shop, the clutches cut out of circuit and screwed fast, while the large pulleys were rewound with rubber covered wire 7 turns in each groove or 14 turns in all on each large pulley. The small pulleys were also rewound with 9 layers of 6 turns = 54 turns of double cotton covered wire in each groove or 270 turns on each pulley. Under these conditions twenty amperes was passed through them for ten minutes with a resulting temperature just high enough to char the cotton slightly. The res: of #2 arm: across brushes 1·220 ohs.

The car was next raised off the floor by jacks, and breaks applied to each driving wheel in turn. The current was shunted from the small pulleys by the resistance box. With 8 amperes = 2160 A.T. on each small pulley and 112 A.T. on each large pulley, the break torque was 100 lbs weight at 5¼" rad: on one wheel, just slipping on the large pulley, and with 14 amperes = 3780 A.T. on each small pulley or 196 A.T. on each large pulley the break torque was 111 lbs weight at 5¼" radius. Total equivalent pull at rad. 760 lbs.

The car was then lowered on the track and attached to a beam by chains through a dynamometer. On releasing the small pulley shunts, the current went up to 56 amperes at the first trial (volts not read) and the indicated pull 1900 lbs. no slip. On the second trial, after a pause to let the small



A B Small pulleys
C D Large "
E Shunt switch.

pulleys cool, there was some slip on the large pulleys, the current being 30 amperes the p.d. at motor terminals 360 volts, p.d. on pulleys 100 volts. Power absorbed by four pulleys 3000 Watts = 4 H.P. The dynamometer pull was 1400 lbs, allowing for index error say 1500 lbs. The resistance of each small pulley = 0.8 ω cool total resistance of all four pulleys warm 3.3 ω.

This armature was then exchanged for the 512 dia. #3 armature having 2.5" of G.S. wire 0.020" between sections and commutator. A test of this armature with 4 carbon brushes was then made under load. The resistance of this armature between brushes is 1.35 ω cool. The motor was belted to a dynamo and the speed gradually raised. The sparking was not excessive at 600 revolutions (full speed) with 45 amperes and 500 volts = 22,500 Watts absorbed in armature but was greater than would be practically desirable. The maximum load however anticipated at this speed is 20 or 25 amperes. This result shews a considerable improvement due no doubt to subdivision of the sections and German silver connections.

The speed of #2 armature was 258 revolutions at 470 volts p.d = 274 at 500 volts. The calculated speed in design was 230, but the entifer has been increased from 1.68 to 2.0 by boring out the field an extra 1/8". If this space could have been saved, the speed expected would have been at 500 volts p.d. 0.84 × 274 = 230. revs.

Measurement of the coefficient of friction between smooth cast iron and smooth wrought iron 17th Nov. 20.

The coeff. when dry was	0.156	by one method of measurement		0.158
	0.160	- one second -		
. . . wet .	0.199	. 1st method		0.205
	0.211	. 2nd -		
. . . oiled .	0.070	. 1st -		0.070
	0.070	- 2nd -		

On the diameter of suspended copper wire whose inductance per mile of 5280 feet shall be 10^4 cm.

From the formula $l = \frac{\mu}{2} + 2 \log_e \frac{2h}{a}$

We have $160,930 \left(0.5 + 2 \log_e \frac{2h}{a}\right) = 1000000$

$$0.5 + 2 \log_e \frac{2h}{a} = 6.215$$

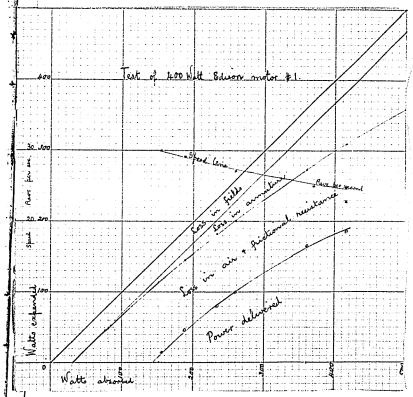
$$2 \log_e \frac{2h}{a} = 5.715$$

$$\log_e \frac{2h}{a} = 2.858$$

$$\frac{2h}{a} = 17.4$$

$$h = 8.7a.$$

No. of Obs.	P.D. on motor	Stalled	Current in motor	Energy in motor	Energy in armature	Calculated Resistance in armature	Difference	Revs. per min.	Revs. per sec.	drop in armature	p.d. in armature
1	122.8	0.047	0.245	30.7				1 –			
2	122.8	0.235	1.226	150.5	120.14	6.7	143.7	1800	30	6.867	115.9
3	124.6	0.245	1.279	154.8	124.7	7.5	147.2	1800	30	7.238	112.76
4	120.8	0.298	1.555	187.8	157.7	12.0	145.7	1752	29.2	9.17	111.63
5	120.0	0.370	1.930	231.6	201.5	19.9	181.6	1704	28.4	11.80	108.2
6	119.2	0.415	2.165	258.1	228.0	25.8	202.2	1632	27.2	13.44	105.76
7	117.0	0.590	3.075	360.1	330.0	56.2	273.8	1500	25.0	19.23	97.17
8	117.7	0.675	3.522	414.5	384.4	75.2	309.2	1488	24.8	22.94	94.76
9	117.6	0.600	3.130	368.1				1488	24.8		



½ HP Test of New Edison Motor. First Trial. 8th Nov. 90.

The machine was floated in the tank and connected by flexible shaft with the Edison 250 Watt motor model that usually stands in the Library. The resistance of the armature between brushes = 0.90 cold = 1.46 hot. Inductance of armature separated from field. 382.4 kilometres. Inductance of a single coil = 15.42 kilometres. Resistance of field 559 cold and 594 hot. Weight of motor 27 lbs.

	E.M.F. furnished per sec. per ∞	Scale Reading	Torque cm. gms.	Energy delivered	Speeds in Rotation	Energy in armat.	Total	Electrical efficiency	Mechanical efficiency	
1		–	–	–	–	–	–	–	–	Field excited
2	3.863	–	–	–	113.7	6.7	150.5	0.758	–	Running light
3	3.759	50 a 16.7	235	15.44	101.8	7.5	154.9	0.757	0.099	Driving dynamo arm. light
4	3.822	200 a 10 50 a 11	2550	45.91	99.8	12.0	187.8	0.776	0.244	Driving under load.
5	3.810	200 a 20 200 a 21	4560	79.86	101.7	19.9	231.6	0.784	0.345	– –
6	3.888	200 a 30 100 a 30 50 a 77	5885	98.68	102.5	25.8	258.1	0.783	0.382	– –
7	3.887	200 a 40 100 a 40 50 a 99	10,700	165.0	108.8	56.2	360.8	0.761	0.458	– –
8	3.821	200 a 50 100 a 50 50 a 121	12,160	185.9	123.3	75.2	414.5	0.746	0.449	– –
9			11,850							after one hour.

The number of wires all round the armature being 2058, and the emf per rev 3.837×10^8 the flux through the armature is 1.864×10^5. The cross section of iron being 12.9 gives a mean density of 14,450

Magnetic measurements with motor 18th Nov. 90.

No. of Obs	Source of EMF	EMF at temp.	Coeff.	Q	Mean thro' div.	φ per div.
7	3 C.C. at 26°C	4.2975	1	4.2975×10^{-7}	171.7	2.503×10^{-9}

	Obtach.	Current thro' field magnet	No of turns	Mean thro'	Res. add	Res. of galv. etc.	Q	$2\pi\phi$	No. of turns	φ	Remarks
	0.037		3	251	0	5250	6.282×10^{-7}	3.298×10^{5}	5	329,800	Flux thro' centre of field magnet
			3	73.7	0	–	1.844×10^{-7}	9.680×10^{4}	5	96,800	Flux through lower part of arm.
			3	75.3	0	–	1.885×10^{-7}	9.896×10^{4}	5	98,960	– – upper . . .

The total useful flux by this method is 1.957×10^5; by the preceding 1.864. Taking the latter, the leakage loss is $1.314 \times 10^5 = 1.314$, and the ratio r is 1.77.

When the motor is running light, and the machine is suddenly disconnected from the mains, the armature comes to rest in 28 seconds. When the brush only is lifted, it comes to rest in 7.5 seconds.

The radius of gyration of the armature is about 6 cms, and its mass 3450 gms. Its moment of inertia may therefore be estimated at 123,000 cm²gms. $\omega = 30 \times 2\pi = 188.5$ $\omega^2 = 35,532$. $\frac{I\omega^2}{2} = 2.173 \times 10^9$ ergs = 217 Joules. To bring the armature to rest in 7.5 seconds requires an expenditure of nearly 29 Watts average retarding activity.

$$i_1 = \frac{220r^2 + 88r + 8.8}{12r^3 + 8.7r^2 + 1.52r + 0.04} \quad ; \quad i_2 = \frac{99r + 22}{(\quad)} \quad ; \quad i_3 = \frac{220r^2 + 99r + 11.0}{(\quad)}$$

$$v_1 = \frac{110r^2 + 44r + 4.4}{(\quad)} \qquad v_2 = \frac{19.8r + 4.4}{(\quad)} \qquad v_3 = \frac{88r^2 + 39.6r + 4.4}{(\quad)}$$

$$v_1 - v_2 = \frac{110r^2 + 24.2r}{12r^3 + 8.7r^2 + 1.52r + 0.04} = 2$$

$$\therefore \quad 55r^2 + 12.2r = 12r^3 + 8.7r^2 + 1.52r + 0.04$$

$$12r^3 - 46.3r^2 - 10.68r + 0.04 = 0$$

$$r^3 - 3.85833 - 0.89r + 0.003333 = 0$$

$$r = 0.0003685 = 3.685 \times 10^{-3}$$

$$r^2 = 0.0000135 8 = 13.5792 \times 10^{-6}$$

$$r^3 = 0.0000000050 = 50.039 \times 10^{-9}$$

$12r^3 = 0.000.0006$
$8.7r^2 = 0.000.118,1+$
$1.52r = 0.005.601.2$
0.04
$0.045.719g.$

$220r^2 = 0.002.987.4$
$88r = 0.324.28$
8.8
$9.127.267$
$i_1 = 199.634$
$v_1 = 99.817$

$99r = 0.364815$
$22.$
22.364815
$i_2 = 4.89.170$
$v_2 = 97.834$

$220r^2 = 0.002.987.4$
$99r = 0.364.815$
11.0
$11.367.802$
$i_3 = 248.640$
$v_3 = 99.456$

$i_1 + i_2 + i_3 = 937.444 \times 0.003685 = 3.4545$ from $55 = 51.5455$ v_1

$i_2 + i_3 = 737.810 \times 0.003685 = 2.7188$ — 2.7188, 48.8267 v_2

$i_3 = 248.640 \times 0.003685 = 0.9162$ — 0.9162, 47.9105 v_3

$i_1 + i_2 = 688.804 \times 0.003685 = 2.5382$ — 51.5455, 2.5382, 49.0073 v_m

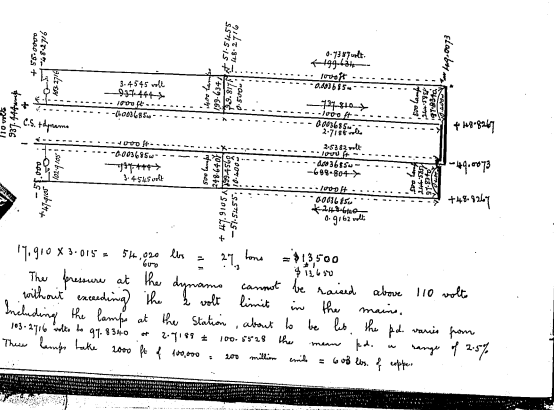
$i_1 = 199.634 \times 0.003685 = 0.7357$ — 0.7357, 48.2716 v_1

(+) 51.5455, v_1 (−) 48.2716, 99.8171

(+) 48.8267, v_2 (−) 49.0073, 97.8340

(+) 47.9105, v_3 (−) 48.5455, 99.456

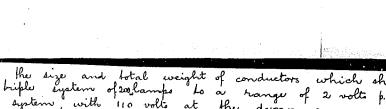
The res: 0.003685ω being of 1000 ft, the res: per foot $= 0.000.003,685\omega$
requiring $\frac{18.0 \times 10^6}{3.685} = 2.985$ million emil per ft. + 6000 ft $= 17.910$ million c.m. ft.



$17.910 \times 3.015 = 54.020$ lbs $= 27\frac{1}{2}$ tons $= \$13500$ (9,400)

The pressure at the dynamo cannot be raised above 110 volt (without exceeding) the 2 volt limit in the mains.
Including the lamps at the Station, about to be lit the p.d. varies from 103.2716 volts to 97.8340 or 2.7188 ± 100.5528 the mean p.d. w range of 2.5%
These lamps take 2000 ft of 100,000 = 200 million emil = 608 lbs of copper.

To determine the size and total weight of conductors which shall limit a given triple system of 2 lamps to a range of 2 volts p.d. on the Werdermann system, with 110 volts at the dynamo.



Let the current to i_1 thro' $\frac{200}{m}$ lamps or $m\omega$, i_2 thro' $\frac{200}{n}$ lamps or $n\omega$, and i_3 thro' $\frac{200}{p}$ lamps or $p\omega$.

Then
$$\left.\begin{aligned} r_1(i_1+i_2+i_3) &+ i_1 m + r_1(i_1) + r_2(i_1+i_2+i_3) - E = 0 \\ r_2(i_1+i_2+i_3) + r_1(i_1+i_2) &+ i_2 n + r_2(i_1+i_2+i_3) - E = 0 \\ r_1(i_1+i_2+i_3) + r_1(i_1+i_2) + r_2(i_1) &+ i_3 p + r_3(i_1+i_2+i_3) - E = 0 \end{aligned}\right\}$$

These simultaneous equations suffice for the determination of i_1 i_2 + i_3.
To abridge the computation let $\frac{r_2}{r_1} = r$, $\frac{r_3}{r_1} = s$, $\frac{E}{r_1} = t$. Then the determinant.

$$\begin{array}{ccc} i_1 & i_2 & i_3 \\ 4r+m & 3r & 2r = E \\ 3r & 4r+n & 3r = E \\ 2r & 3r & 4r+p = E \end{array} \quad \text{Set } \frac{m}{r} = \mu \quad \frac{n}{r} = \nu \quad \frac{p}{r} = \varpi \quad \text{and } \frac{E}{r} = c$$

$$i_2 = \frac{c}{\Delta}\begin{vmatrix} 4+\mu & 1 & 2 \\ 3 & 1 & 3 \\ 2 & 1 & 4+\varpi \end{vmatrix} ; \quad i_1 = \frac{c}{\Delta}\begin{vmatrix} 1 & 3 & 2 \\ 1 & 4+\nu & 3 \\ 1 & 3 & 4+\varpi \end{vmatrix} ; \quad i_3 = \frac{c}{\Delta}\begin{vmatrix} 4+\mu & 3 & 1 \\ 3 & 4+\nu & 1 \\ 2 & 3 & 1 \end{vmatrix}$$

and $\Delta = 12 + 7\mu + 12\nu + 7\varpi + 4\mu\nu + 4\mu\varpi + 4\nu\varpi + \mu\nu\varpi$

$\therefore$ $i_1 = 2 + 2\nu + \varpi + \nu\varpi \times \frac{c}{\Delta}$ and pressure $v_1 = 2r(2 + 2\nu + \varpi + \nu\varpi)\frac{c}{\Delta}$

$i_2 = \mu + \varpi + \mu\varpi \times \frac{c}{\Delta}$ $\qquad v_2 = r(\mu + \varpi + \mu\varpi)\frac{c}{\Delta}$

$i_3 = 2 + \mu + 2\nu + \mu\nu \times \frac{c}{\Delta}$ $\qquad v_3 = p(2 + \mu + 2\nu + \mu\nu)\frac{c}{\Delta}$

$\therefore$ $i_1 = \frac{E}{r^2\Delta}(2r^2 + 2\nu r + \varpi r + n\varpi)$ $\qquad v_1 = \frac{mE}{r^2\Delta}(2r^2 + nr + \varpi r + n\varpi)$

$i_2 = \frac{E}{r^2\Delta}(\quad mr + \varpi r + m\varpi)$ $\qquad v_2 = \frac{nE}{r^2\Delta}(\quad mr + \varpi r + m\varpi)$

$i_3 = \frac{E}{r^2\Delta}(2r^2 + mr + 2\nu r + mn)$ $\qquad v_3 = \frac{pE}{r^2\Delta}(2r^2 + mr + nr + mn)$

Given the values $m = 0.5$ $\quad n = 0.2$ $\quad p = 0.4$ $\quad E = 110$

$$i_1 = \frac{220r^2 + 22r + 4.4r + 8.8}{12r^3 + 8.7r^2 + 1.52r + 0.04} \qquad v_1 = \frac{110r^2 + 22r + 4.4}{12r^3 + 8.7r^2 + 1.52r + 0.04}$$

$$i_2 = \frac{55r + 4.4r + 22}{12r^3 + 8.7r^2 + 1.52r + 0.04} \qquad v_2 = \frac{11r + 8.8r + 4.4}{12r^3 + 8.7r^2 + 1.52r + 0.04}$$

$$i_3 = \frac{220r^2 + 4.4r + 22r + 11}{12r^3 + 8.7r^2 + 1.52r + 0.04} \qquad v_3 = \frac{88r^2 + 26.4r + 4.4}{12r^3 + 8.7r^2 + 1.52r + 0.04}$$

$$v_1 - v_2 = \frac{110r^2 + 13.2r}{12r^3 + 8.7r^2 + 1.52r + 0.04} = 2$$

$$\therefore \quad 110r^2 + 13.2r = 24r^3 + 17.4r^2 + 3.04r + 0.08$$

$$24r^3 + 6.4r^2 - 10.16r + 0.08 = 0$$

$$r^3 - 3.86r^2 - 0.423\,4r + 0.003333 = 0$$

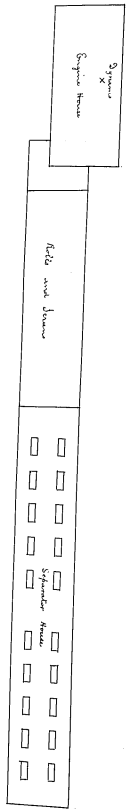
The solution of this is nearly $r = 0.0073$ $\quad r^2 = 0.0000533$ $\quad r^3 = 0.0000000389$

$$i_1 = \frac{-0.011726 + 0.4818 + 8.8}{0.0004664 + 0.011096 + 0.04} = \frac{9.2935}{0.051560} = 180.25 \qquad v_1 = 90.125$$

$$i_2 = \frac{0.7227 + 22}{0.051560} = 449.250 \qquad v_2 = 88.160$$

$$i_3 = \frac{0.011726 + 0.4818 + 11}{0.051560} = 222.95 \qquad v_3 = 89.180$$

If + corresponds to 1000 feet the res: per foot $= 0.0000073\omega$ per foot
$= 1500\,000$ emil and there has to be 6000 feet $= 9,000,000$ emil



Ground Plan of Refining Mill Ogdensburg N.J. 1/32" to 1 foot or 1/384 actual size.

On the apparatus required for the Ore Separating Mill at Ogdensburg (13)

The original series of 13 magnets (26 bobbins) was designed to operate at a p.d. of 110 volts see Book II p. 119-120, but 3 more magnets have since been added to the outfit of each series making 16 in all and raising the necessary pressure to $\frac{16}{13} \times 110 = \frac{1760}{13} = 135.5$ volts. To this estimate allowance has to be made say 5 volts for leads to generator, + 15 volts margin for any emergencies = 160 volts.

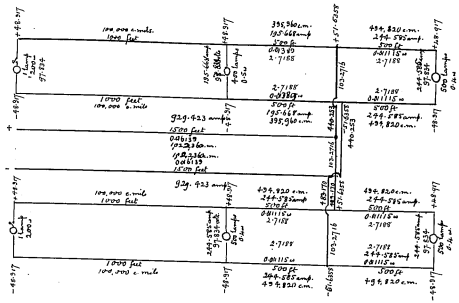
The distance from the dynamo to the center of the ~~partition in the~~ separator house is 275 feet. Allowing ½ volt in these leads = 2 each way, we have 35 amperes for each machine, and there will ultimately be 20 = 700 amperes carried 275 feet at 2 volts drop = $\frac{192,500}{2} = \frac{962,500}{96}$ = 1058 *

These cables should therefore have 1,000,000 cmil. each. 600 feet of this cable should be ordered.

From the centre of this room to any machine is under 100 feet. Allowing 1 volt drop in these leads or 0.5 each way we have $\frac{35 \times 100}{0.5} = 70$ of #7 77,000 c.mils say #2 B.W.G. The nearer one might be smaller. say 40,000 cmils #6 B.W.G.

A trial was made on the 23rd November, of the amount of power required to drive the experimental plant in the Ore Milling Building. There were 16 magnets in series, taking 143 volts and 37 amperes = 5291 Watts = .7 H.P. and the motor running the belt pulleys at 62 revs. per min. took 120 volts + 40 amperes = 4800 Watts = 6.4 H.P. Total 10,091 Watts or 13.3 H.P.

To determine the size and weight of conductors necessary to operate the hypothetical system shown on page 12 by the aid of feeders, keeping the same difference of pressure in the mains as exists in the last case.



The mains are of three sizes

4000 feet of	#100		= 400 million c.m.ft.
3000 - -	#494		1,484,460,000
1000 - -	#396		395,960,000
	6575 lb.	Total in main	2,280,420,000
The feeders are for 30 volts drop	#1022	3000' 9,774 lb	3,067,080,000
		16,722 lb. Total in system.	5,347,500,000 cmf

@ 25¢ per lb - $4.030

Test of the Safety Conduit Tubes referred to in Book III. p. 105 + 118. 26th November 20.

These tubes have been immersed in the tank on the roof under water since the 21st August 97 days in all. Their mechanical appearance is inferior, the outside paper being very weak. Three tubes were selected, and plugged with paraffined cork well coated over with paraffine wax. G.P. covered wires passed watertight through one cork. The tubes being filled with tap water. The resistances observed were

#1	110,000 ω	by Bridge 6 volts 1000/1000	21C
#2	60,000 ω	- - - - - -	
#3	17,000 ω	- - - - - -	
1,2,+3	4,950 ω		

Each length 80 feet, 50000 ω for 30 feet = 150,000 ω per foot.
or 28·5 ω per mile

Loss. from 144 volts 4 amperes or 456 Watts per mile
- - 456 - 16 - - 7296 - - -

With one conductor in each tube making contact all round

Measurement of Inductances mh = millihenry = Myriametre.

Telephone, Ordinary Bell type 168,969 A 1000/100 76.75ω - 0.93ρ = 0.07138
including leads .455 = 71.38mh

Same with the diaphram removed 77.40ω 0.61ρ = 47.22mh 66.1%

Telephone. Special high resistance Bell type
161,463 A including 0.455ω lead 1000/100 851.9ω 0.203ρ = 173mh.

Same with diaphram removed 0.145ρ = 123.5mh. 70.8%

Telephone, Ordinary Bell type, 175,805A 1000/100 75.45ω 1.05ρ = 79.23mh

Same with diaphram removed 75.44 0.63ρ = 47.53mh. 60%

Long distance telephone apparatus in the accountants office

Telephone. Ordinary Bell type 1000/100 74.70ω 1.34ρ = 100.1mh
all three wires like the leads 0.322

Same with diaphram removed 74.60 0.87ρ = 64.9 64.9%

Bell in the apparatus, as set 10,000/1000 79.83 1.705ρ = 1.361 H

Induction coil Primary 10,000/100 0.587ω 0.600 = 3.522mh

Secondary 1000/100 163.88 4.48 = 734.2mh

Mutual inductance 1000/100 163.88ω 4.89ρ $\frac{801.4 - 734.2}{1.1}$ = 61.1mh
reversed - - 4.09 = $\frac{734.2 - 670.2}{1.1}$ = 58.2mh

Mean = 59.65mh

Inductor (call magneto) armature in the same apparatus $\frac{10000}{1000}$ 555.7ω 6.32ρ 7.336 H

555.7ω 0.485ρ = 2.695 H

Western Union Relay, Armature far back (leads included) 0.3ω
140ω type

$\frac{10,000}{1,000}$ 139.75ω 2.5ρ = 3.469 H.

500ω in cct. $\frac{10,000}{1,000}$ 638.6 0.5ρ = 3.193 H

Armature hard down " " 1.5ρ = 3.579 H.

W.U. Relay, Armature far back $\frac{10000}{1000}$ 650.3 0.465ρ = 3.026 H. 500ω in cct
140ω type " hard down 850.3 0.360 = 3.06 H.
" " 850.3 5.6 = 3.50 H. 700ω . .

W. U. Relay " far back $\frac{10000}{1000}$ 838.5 0.360 = ~~7.44 H.~~ 2.516 H. 700ω in cct
140ω type " average practical set " 0.775 = ~~13.2 H.~~ 4.82 H
" hard down on magnets " 4.9 = ~~44.1 H.~~ 7.55 H

W. U. Relay " far back $\frac{10000}{1000}$ 209.8 0.091 = 191mh. 200ω in cct + leads
10ω type " hard down - - 0.22 = 462 mh. - - - - -
" far back - 60.07 0.35 = 210 mh. 50ω - - - -
" hard down - - 0.82 = 493 mh. - - - - -

Pony Sounder - hard up $\frac{10000}{100}$ 6.625 0.431 = 285mh. 0ω - - - -
" - down - - 0.485 = 32.2 mh. 0ω - - - -

Pony Sounder - - up $\frac{10000}{10}$ 5.596 0.42 = 23.5 mh. 5ω - - - -
" - down - - 0.83 46.46 mh. 5ω. - - - -

Large vertical induction coil primary $\frac{10,000}{10}$ 0.3355ω 1.78ρ = 5.97 h.
leads 0.2617ω res. 0.07380

T.D. 20°C. Secondary $\frac{10000}{100,000}$ 155.10ω 2.825ρ = 436 H
.9975 - cct. 15.471 ω (true ohms)

μ $\frac{.9975}{99.750}$, 155.10ω = 15.471 true ohms, + 2.71ρ } = 16.1 H
reversed 2.94ρ }

Large horizontal induction coil, Secondary $\frac{100,000}{10,000}$ = 30,545ω
$\frac{99,750}{10,000}$ = 30,463ω true } mean 58ρ = 1520H

balance at $\frac{100,000}{13,000}$ = 39,795ω
30,580ω legal
= $\frac{99,750}{15,967}$ = 30,510ω true 5ρ = 1,978 H

primary 1000/10 = 0.2970ω legal 4.42ρ = 13.1 h
leads 0.1324ω = 0.1430ω

Mutual inductance 4.55ρ. 163 H. Secondary $\frac{100,000}{13,350}$ = $\frac{99,750}{13,100}$ = 40,780ω = 30,600ω legal
= 30,530ω true = 1,978 2,036 H

---

19 + 9.43 = 28.43 - 20 = 8.43 × 0.03 = 0.2529 ρ. = 39 = 15471
0.99747

5.4 X 0.03 = 0.252 X 52,57 = 13 .
1000 . 1002.5

Data relating to experimental induction Coil

A cylinder of insulating composition (6.5 long) and 2.7 in diameter was wound with # 73 turns of double ~~silk~~ cotton covered wire of 22 B.W.G. 0.025" (0.063) covered to 0.031" (0.081). The length of the helix is 60.75 so that there are 12.07 turns per cm. Over this solenoid fits loosely a shorter one 14.85 long between flanges wound with turns of paper covered copper wire No. 22 B.W.G. 0.028" (0.07) covered to 0.031" (0.079). This second helix rests at the centre of the first.

The resistance of the central helix is 3.70 ω. and its inductance is 7.53 kilometres = 753 microhenries

The area of the mean diam. of the helix (1.060" + 0.032) = 1.092" = 2.774 cm. = 6.04 sq. cm. so that the field is being 12.57 X 12.07 = 151.8. The flux per unit current = 917.2

The inductance per cm. should be 11,080 and the total inductance 673000 cms = 6.73 kilometres. = 673 microhenrys.

The mutual inductance between the solenoid and the outer helix should be 917.2 per turn of the latter (in cms).

A Hughes bridge was arranged, and the inductance of a certain coil measured with an interrupter of low frequency. The inductance of this coil by bridge and secohmeter was 1000/10, 0.867, 0.0244 = 208 microhenrys. Balance was obtained for steady currents with telephone at 22.5 and 5 on the Porcelain scales. Total res: in bridge 100 + 5 + 17 = 122. Balance was nearly obtained for interrupted currents with 50 wires in circuit on the secondary helix ∴ μ = 45,860. Hence L = $\frac{45,860 \times 122}{22.5}$ = 248,700 cms = 249 microhenrys.

Data of Ballistic Galvanometer remounted 5th December

Bridge	Bridge Ratio	Temp. of Bridge	Temp. of Bridge for Log.	Temp. of Bridge for 1002.5 Ω	Observed Res:	Res: add'd for temp. to 105.30	Temp. of Galvo:	Capacity	Inductance	Log.	
	1000/1000	20°C	19°	28.4	5257 ω	5270 ω	21.2°C & Th:	0.380	2.008 H	0.4	

The last measurement was made on the 3rd Oct: 1889 Book II p. 64.

Inductance of the speaking wire

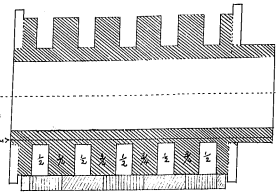
Ratio 1000/1002.5 Res: 2253.5 / 2258 Capy 1.58 μ

3.57 H

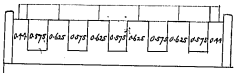
Pulley No 2 ..... Axial Section $\frac{1}{2}$

Ratio of iron to winding breadth $\frac{0.375}{.75} = 0.50$

Tooth ... line



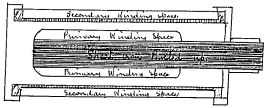
Pulley No 3.
Ratio of walls to winding breadth
$\frac{0.3125}{0.575} = 0.57$

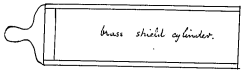


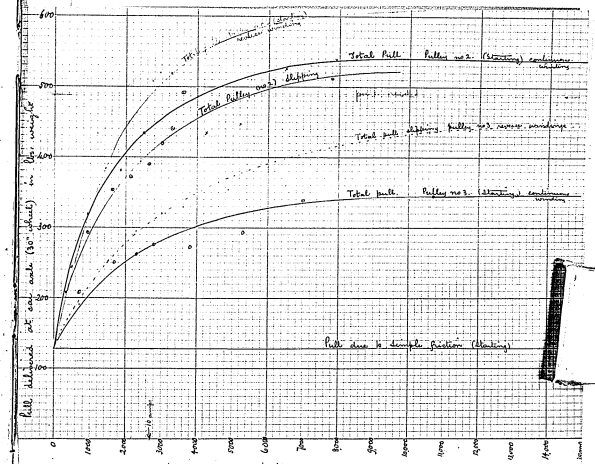
On the best windings for the experimental Street Car Pulleys received from Schenectady

Pulley no 2 received from Schenectady, and that with which the experiments detailed on p. 9 were made, was wound with 2710 turns of # 17 B.W.G. copper wire 0.058".

Full size cross section of coils and shielding cylinder.







Data and description of a small medical induction coil to be operated by the Edison Lalande battery.

The primary winding consists of 6 layers? of 77 turns say 450 turns of # 23 B.W.G. 0.025" covered to 0.030".
The secondary winding consists of 6 layers? of 190 turns say 1140 turns of # 32 B.W.G. 0.007" covered to 0.013".

The inductance of the primary	100~/10	1.092	4.5Ω	= 0.00496	
" " " secondary	100~/100	785	1.27	= 4.9 mh. = 0.0097 h = 99.7 μh	
" mutual " " "	for 1 sec.	7850	1.92	= 0.0111 h = 18.3 mh	
" " " " " reversed	100~/100	78.62	0.95	= 0.0224 h = 22.4 mh	

Mean value 20.55 mh

No change appreciable in the mutual inductance when brass shield cylinder is inserted.
The resistance of the primary is 0.79 Ω
" " secondary is 78.2 Ω a ratio of nearly 100.

This induction coil is operated by one bichromate cell whose zinc plate, amalgamated, is a rod 11.5 long 0.9 in diam. and immersed to about 10 cm in depth exposing some 28 sq. cm. of surface, while the carbon plate is 10.0 × 7.0 × 0.7 immersed to about 8.0 cm exposing some 56 sq. cm. The distance between plate and rod ~~being~~ is about 2 cm.

The E.M.F. of this cell is 2.0 volts, and its internal resistance 1.0 Ω at its lowest. The current it gives through the closed primary circuit is 1.13 amp, and when operating the contact breaker 0.33 amp.

Two small Edison-Lalande cells of the telephone type were connected in series. Their e.m.f. = 1.49 volts, their combined int: res: 0.73 Ω. The current on closed primary = 1.0 ampere.

Test of the power of one of the magnetic pulleys last used at Schenectady 29th Nov. 20.

Clock: Reading 2 x	Ampere	Reading of Ammeter	Accepted current	Ampere turns in the 5 glasses of pulley	Weight	distance	Total Moment in ft. lbs.		Equivalent pull at any end lbs. wt.	
0.000	0	0.0	0	0	40 lbs.	4.8"	160		128	
0.128	1.31	1.5	1.3	351	~~+~~ + 24	50"	200	(100)	208	80
0.320	4.00	4.5	4.0	1080	+48	60"	480	240	320	192
0.655	6.72	8.0	6.7	1810	+48	79".	476	316	381	252
-	-	10.0	9.4	2540	+48	96".	544	384	435	307
.17	12.0	12.0	12.0	3240	+67	87.5"	649	489	519	391
-	-	16.0	15.7	4240	+85	54"	543	383	435	307
1.88	19.3	20.0	19.3	5210	+85	56.5	560	400	448	320
2.35	24.1	27	24.1	6510	+85	70.25	658	498	527	399
2.60	26.7	30	26.7	7210	+85	-	-	-	-	-
2.85	29.2	35	29.2	7885	+85	72.5	674	514	539	411
5.2	53.4	44	53.4	14420	+85	63.5 ?	610	450	488	360

In the case presented $E = 80$ $C = 50$ $t = 4000$

$n = \frac{500}{60} = 8.33$

$R = 28.9$ $r = 23.4$ $R - r = 5.5$

Assume the constants $b = 1.0 \times 10^{-4}$

$f = 500$

$a = 0.9$ $a\eta = 0.8$ $a^2\eta^2 = 0.65$

$g = 0.9$

$\rho = 1.8 \times 10^{-6}$

$p = 4$

$l = 1$ (trial)

$h = 0.98$

$$b = \frac{4000 \times \sqrt[3]{\frac{80 \times 0.02 \times 0.65 \times 23.4 \times 23.4 \times 16 \times 1}{2 \times 50 \times 0.98 \times 1.8 \times 10^{-6}(10+6)}}}{2 \times 500 \times 9.86 \times 10^{4} \times 4 \times 0.98 \times 8.33 \times 0.65 \times 23.4 \times 23.4 \times 5.5 \times 10^{-8}}$$

$$= \frac{4000 \times \sqrt[3]{\frac{9112}{2823 \times 10^{-6}}}}{63070}$$

$$= \frac{400000 \sqrt[3]{3.228}}{63,070} = \frac{400000 \times 1.478}{63,070} = \frac{591,120.000}{63,070}$$

$$= 9.37$$

b is shown as 16.8. Retaining this and reducing $R - r$ in the ratio $\frac{9.37}{16.8} = \frac{5.5 \times 9.37}{16.8} = 3.068$ 3.1 say. and $r = 25.8$

$\varphi = 2 \times 10,000 \times 3.1 \times 25.8 = 1,600,000$ useful lines

$\varphi = 800,000$ useful lines.

$w = \frac{8.0 \times 10^{8}}{1.0 \times 10^{4} \times 5.33 \times 0.9} = \frac{8.0 \times 10^{3}}{5.340} = 0.90$ say 0.90.

$= 270$ wires per quadrant.

The circumference of $25.8 = 10'' = 62.8'' \times 0.9$. $56.52 \div 0.90 = 0.05$

When uncovered this wire will be $0.050''$ say. $= 2500$ c.mil, and 12.5 amp 200 c.mile per amp.

Calculations for a proposed form of Marine Quadripolar Dynamo on a design of Mr Phelps Eng. Dept. N.Y.

(19)

Consider the general equations of a multipolar gramme ring dynamo, carried to the first approximation

Let r = the int: radius of the armature core (cms)

R = " ext: " " " " (cms)

b = " breadth " " " (cms)

d = " diameter — " " copper wire on armature. (cms)

$\mathcal{D}$ = " " — " " " " covered. (cms)

w = " number of the wires counted all round.

φ = " polar flux (Coslines)

p = " number of poles

l = " number of layers of wire on the armature.

ρ = " permissable density of current in the wire (amp) per sq cm.

E = " energy developed electrically (watts)

$\mathcal{E}$ = " electrical effic energy delivered (watts)

b = " density of induction in the core-space (C.G.S)

a = " constant of reduction for armature winding space

g = " " " " wire covering or ($\frac{\mathcal{D}}{d}$)

c = " current generated in the wire at full loading

C = " total " " " armature " " amp

E = " volts generated

e = " " at machine terminals on full load.

h = " ratio of e to E

n = " number of revs. of the armature per second.

Then

$$E = \varphi n w \times 10^{-8} \quad (1)$$

$$e = h \varphi n w \times 10^{-8} \quad (2)$$

$$\varphi = 2\mathcal{E}(R - r)b \quad (3)$$

$$t = \tfrac{1}{2} e C = Ch\varphi n w \times 10^{-8} = pc\rho\varphi n w \times 10^{-8} \quad (4)$$

$$\mathcal{D} = \frac{a 2\pi r l}{w} \quad (5)$$

$$d = \frac{a g l 2\pi r}{w} \quad (6)$$

$$c = \rho \frac{\pi}{4} \frac{a^2 g^2 4\pi^2 r^2 l^2}{w^2} \quad (7)$$

$$\therefore t = \rho \frac{\pi}{4} \cdot \frac{a^2 g^2 4\pi^2 r^2 l^2}{w^2} \cdot p h \varphi n w \times 10^{-8} \quad (8)$$

$$= \rho \frac{\pi}{4} \cdot \frac{a^2 g^2 4\pi^2 r^2 l^2}{w^2} \cdot p h \cdot 2\mathcal{E}(R - r) b n w \times 10^{-8} \quad (9)$$

$$t = \frac{2\rho \pi^2 \mathcal{E} b p h n a^2 g^2 r^2 l^2 \times 10^{-8}(R - r)}{w} \quad (10)$$

$$Q = \frac{w^2 \mathcal{E} 2(b + R - r)}{\frac{\pi}{4}(d^2)} = \frac{w^2 \mathcal{E}(b + R - r)\rho}{\pi a^2 g^2 4\pi^2 r^2 l^2} \quad (11)$$

where Q is the resistance of the other wire in series of rev. between brushes and ρ resistivity per in ohms, of the wire

$$q = \frac{2 w^2 \mathcal{E}(b + R - r + ld)}{a^2 g^2 \pi^2 r^2 \rho^2 l^2} \quad (12)$$

$$Cq = e\left(\frac{1 - h}{h}\right) \quad (13)$$

$$\therefore w^3 = \frac{e(1 - h) a^2 g^2 \pi^2 r^2 \rho^2 \mathcal{E}}{2Ch\rho(b + R - r + ld)} \quad (14)$$

$$\therefore t = \frac{2\rho \pi^2 \mathcal{E} b p h n a^2 g^2 r^2 l^2 \times 10^{-8}(R - r)}{\sqrt[3]{\frac{e(1 - h) a^2 g^2 r^2 \rho^2 \mathcal{E}}{2Ch\rho(b + R - r + ld)}}} \quad (15)$$

$$\text{or } b = \frac{t \sqrt[3]{\frac{e(1 - h) a^2 g^2 r^2 \rho^2 \mathcal{E}}{2Ch\rho(b + R - r + ld)}}}{2\rho \pi^2 \mathcal{E} p h n (a^2 g^2 r^2 l^2)(R - r) \times 10^{-8}} \quad (16)$$

And this is the evaluation of b to a first approximation from R, r, e, C and known constants.

Calculations for a 4 kilowatt dynamo designed by the Engineering Department. Continued. See also p.83

$(R-r)$ is 5·5 and b is 16·8, the cross section is 92·4 sq. cms and allowing 9000 per sq. cm gives 831,600 lines usefully conducted or 1,663,200 lines for φ. n. = 5·33 φn = 1·3856 × 10⁷ ∴ $w = \frac{500}{1.386} =$ 577·3 ~~mmf 600~~. Having ample space say 800. The int: diam: being 1·2 × 2" = 18·4" the int: circumference is 57·8" and the breadth per wire = 0·072". Allowing 0·012" this becomes 0·060", nearest size 0·058" #17 B.W.G. C. mils 3364 = 260 c.m. per amp.

The value of r may be taken as 1·6 so that φ in the core will be 1·6 × 1216,000 = 1,945,000 and in wrought iron with B = 12,000 = 162 sq. cms. = ~~164~~ 81 sq. cms. in each core = 10·2 cms = 4" in diameter; allow ~~4.5~~ 4·0.

The polar area is 14 × 16 sq. cms = 224 sq. cms. and the entifer will be 0·10" + 0·070" + 0·125" = 0·205" = 0·5 cm so that the total air reluctance is $\frac{1.0}{224}$ = 0·00445 lucks.

The reluctance of the rest of the circuit will be 0·0045. Total 0·009

The m.m.f. needed for 972,000 lines = 10,000. = 8000 amp. turns = 5300 turns on each core, each offering 27·5 w hot. The mean turn being 1·25 feet there will be 6660 feet per core = 5328 ft per ohm = #15 B.W.G. 0·072". @ 7·88 lbs = 99 lbs. on each.

Allowing 2 amperes per core, the turns are 4000 offering 19·0 w hot = 5000 feet or 500 ft per w = #15 B.W.G. 0·072 @ 7·88 = 79 lbs.

For 607,000 lines 6000 mmf are needed = 4800 J.T. = 2400 turns offering 10 w = 3000 feet = 300 ft per w = #17 B.W.G. 3000' = 30 lbs. of wire.

Requirements 30 lbs of #17 B.W.G. 0·058" on each core or 120 lbs. in all

1 layer of #17 B.W.G. on the armature in 800 turns = 200 per sector, and 200 commutator blocks.

Experiment on the effect of an aqueous solution of Tetra-ethyl ammonium injected into the arterial system of a rabbit. 1st December 90

It was found that 300 divisions, supposed to be minim divs. of the hypodermic injector scale represent 28·8 c.c. so that each div: represents 0·073 c.c.

After cleansing the injector first with carbolic acid and then with boiling water, injected 0·25 c.c. of the 1% solution in water of tetraethylammonium into the vein on the right ear of the small white rabbit at 16 o'clock.

On the following morning injected 0·5 c.c. of the same solution into the two ears of the same rabbit at 9 o'clock.

On the 3rd Dec. 0·5 c.c. of 1% solution was injected into the left ear of the larger rabbit.

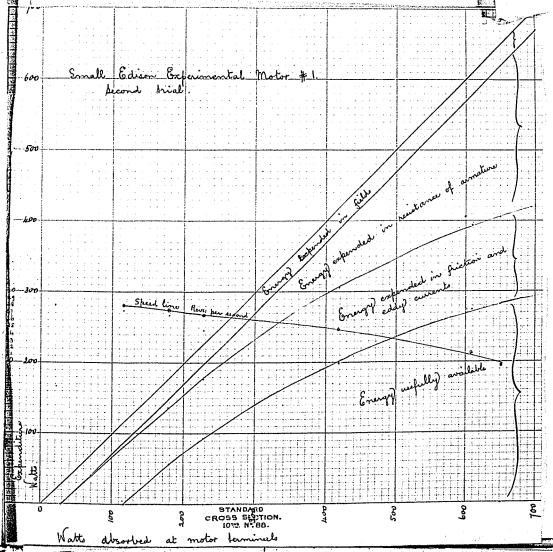
On the 4th Dec. 0·75 c.c. of 1·7% solution was injected into the right ear of the larger rabbit.

On the 6th Dec. 0·75 c.c. of 3·0% solution was injected into the right side of the larger rabbit.

On the 8th Dec. 0·75 c.c. of 3·0% solution was injected into the right side of the smaller rabbit.

On the 10th Dec. 1·0 c.c. of 3·0% solution in flow pills was administered to the larger rabbit by the mouth

No. of Obs.	P.D. on motor	Watts	Current in motor	Energy in motor	Energy in field	Energy in armat.	Calculated new Eff. in armat.	Difference	Revs. per min.	Revs. per sec.	drop in armat.	p.d. in armat.
1	122.5	0.046	0.236	28.9	28.9	0	0	0	~~1685~~	~~28.42~~		-
2	122	0.185	0.949	116.2	28.9	87.3	4.2	83.1	1685	28.60	5.92	116.6
3	"	0.285	1.462	179.1	~~150.~~	150.2	12.48	137.7	1645	27.42	10.18	112.3
4	"	0.362	1.857	227.5	"	198.6	21.80	176.8	1695	26.75	13.45	109.0
5	"	0.665	3.411	417.8	"	388.9	83.66	305.2	1478	24.63	26.35	96.6
6	"	0.970	4.976	609.5	"	580.6	186.5	394.1	1271	21.18	39.35	83.1
7	"	1.035	5.309	650.3	-	621.4	213.6	407.8	1177	19.62	42.10	80.4
8	"	1.300	6.668	816.8	-	787.9	392.4	395.5	910	15.16	61.10	61.4



Test of small Edison motor Second Trial 2nd Dec: 90.

The machine has been been fitted with a new field magnet, and the same field wire has been transferred from the old field at a loss in turns, owing to the shellac adhering to the wire. The shaft has been increased to 0.5", and the armature connections have been made to the commutator through 0.01" platinoid wire

Hours & Min. for test	Scale	Reading	Torque	Energy delivered Watts	Energy lost in friction	Energy lost in armature wire	Total	Electrical Efficiency	Mechanical Efficiency	Remarks
0	0	0	0	·0						Field only
4.250	0	0	0	0	83·1	4·2	87·3	0·715	·0	Running light
4.095	{·50 @ 8 200 @ 25}	3400	57·5	80·2	12·5	150·2	0·769	0·321		Driving dynamo light
4.075	{50 @ 17 200 @ 24}	5650	93·2	83·6	21·8	198·6	0·777	0·41		- dynamo now in sep: excited field
3.902	{50 @ 12·3 100 @ 25 1000 @ 10}	13,115	199·2	106·0	83·7	388·9	0·730	0·477		load 107·5 v 0·9 a
3.924	{50 @ 18·1 1000 @ 20}	28905	273·0	121·1	186·5	580·6	0·646	0·448		- " 2 amp
4.100	{50 @ 16·2 500 @ 5 1000 @ 20}	23315	282·0	125·8	213·6	621·4	0·656	0·434		87 v 2·5 amp
4.050	{50 @ 13 200 @ 8 500 @ 15 1000 @ 20}	29,150	272·4	123·1	392·4	787·9	0·502	0·334		3·6 amp

The temp: on the armature was to 200°F after the run of about 20 minutes. The res: of the armature very warm is 9·55 v, and fairly warm 8·32. The field warm 6·30 v.
Weight of machine with base 37½ lb

Convention. The quantity discharged through an electromagnetic circuit traversed by a steady current, after the removal of that current by a short circuit, is called the charge of that circuit.

Charging

The natural logarithm of the ratio of the $\left\{\begin{matrix}\text{charge}\\ \text{initial current}\end{matrix}\right\}$ to the $\left\{\begin{matrix}\text{deficit of charge}\\ \text{charging current}\end{matrix}\right\}$ at any instant is the quotient of the charging time during which charge has been in progress by the time constant of the circuit.

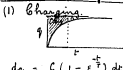
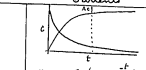
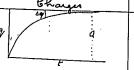
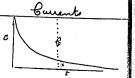
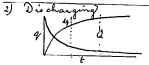
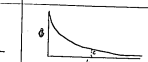
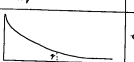
Discharging

The natural logarithm of the ratio of the $\left\{\begin{matrix}\text{charge}\\ \text{initial current}\end{matrix}\right\}$ to the $\left\{\begin{matrix}\text{residual charge}\\ \text{discharging current}\end{matrix}\right\}$ at any instant is the quotient of the time during which discharge has been in progress by the time constant of the circuit.

The charge is the quantity which would traverse the circuit if the initial charging current were active for a time equal to the time constant of the circuit.

The energy of the charge is equal to half the energy that would be developed by the initial charging current if sustained uniformly, against the resistance of the circuit, during a time equal to the time constant of the circuit.

On some interesting relationships between closed electromagnetic circuits and condensers.

	Inductances. Charges	Inductances. Currents	Permittances. Charges	Permittances. Currents
(1) Charging				
	$dq = C(1-\varepsilon^{-\frac{t}{T}})\,dt$ $= C\,dt - C\varepsilon^{-\frac{t}{T}}\,dt$ $q = Ct + CT(\varepsilon^{-\frac{t}{T}}-1)$ $= Ct + Q(\varepsilon^{-\frac{t}{T}}-1)$ $Q-q = Q(\varepsilon^{-\frac{t}{T}}-1)$ $Q-q = Q(1-\varepsilon^{-\frac{t}{T}})$ Charge $= Q(1-\varepsilon^{-\frac{t}{T}})$ $\frac{\text{Charge}}{Q} = 1-\varepsilon^{-\frac{t}{T}}$ $\frac{\Delta q}{Q} = \varepsilon^{-\frac{t}{T}}$ $\log_e \frac{Q}{\Delta q} = \frac{t}{T}$	$c = C(1-\varepsilon^{-\frac{t}{T}})$ $\frac{c}{C} = 1-\varepsilon^{-\frac{t}{T}}$ $\frac{c-C}{C} = -\varepsilon^{-\frac{t}{T}}$ $\frac{C-c}{C} = \varepsilon^{-\frac{t}{T}}$ $\frac{\Delta c}{C} = \varepsilon^{-\frac{t}{T}}$ $\frac{C}{\Delta c} = \varepsilon^{\frac{t}{T}}$ $\log_e \frac{C}{\Delta c} = \frac{t}{T}$	$\frac{dq}{dt} = \frac{c-q}{T}$ and $v = \frac{q}{f}$ $\frac{dq}{dt} = \frac{C}{f} - \frac{q}{fT} = \frac{C}{f} - \frac{q}{T}$ $q = \varepsilon^{-\int\frac{dt}{T}}\int\varepsilon^{\int\frac{dt}{T}}(\frac{C}{f}dt + K)$ $= \varepsilon^{-\frac{t}{T}}(\frac{C}{f}\varepsilon^{\frac{t}{T}}dt + K)$ $= \varepsilon^{-\frac{t}{T}}\frac{C}{f}(\varepsilon^{\frac{t}{T}}-1) + K\varepsilon^{-\frac{t}{T}}$ $= Q(1-\varepsilon^{-\frac{t}{T}}) + 0$ $\frac{q}{Q} = 1-\varepsilon^{-\frac{t}{T}}$ $\frac{q-Q}{Q} = -\varepsilon^{-\frac{t}{T}}$ $\frac{Q-q}{Q} = \varepsilon^{-\frac{t}{T}}$ $\frac{\Delta q}{Q} = \varepsilon^{-\frac{t}{T}}$ $\frac{Q}{\Delta q} = \varepsilon^{\frac{t}{T}}$ $\log_e \frac{Q}{\Delta q} = \frac{t}{T}$	$\because q = Q(1-\varepsilon^{-\frac{t}{T}})$ $c = C - \frac{Q}{fT}(1-\varepsilon^{-\frac{t}{T}})$ $= C - C(1-\varepsilon^{-\frac{t}{T}})$ $= C\varepsilon^{-\frac{t}{T}}$ $\frac{c}{C} = \varepsilon^{-\frac{t}{T}}$ $\frac{C}{c} = \varepsilon^{\frac{t}{T}}$ $\log_e \frac{C}{c} = \frac{t}{T}$
(2) Discharging				
	$c = C\varepsilon^{-\frac{t}{T}}$ $dq = C\varepsilon^{-\frac{t}{T}}dt$ $q = -CT(\varepsilon^{-\frac{t}{T}}-1)$ $\frac{q}{Q} = 1-\varepsilon^{-\frac{t}{T}}$ $\frac{q-Q}{Q} = -\varepsilon^{-\frac{t}{T}}$ $\frac{Q-q}{Q} = \varepsilon^{-\frac{t}{T}}$ $\frac{\Delta q}{Q} = \varepsilon^{-\frac{t}{T}}$ $\log_e \frac{Q}{\Delta q} = \frac{t}{T}$	$c = C\varepsilon^{-\frac{t}{T}}$ $\frac{c}{C} = \varepsilon^{-\frac{t}{T}}$ $\frac{C}{c} = \varepsilon^{\frac{t}{T}}$ $\log_e \frac{C}{c} = \frac{t}{T}$	$-\frac{dq}{dt} = \frac{q}{T}$; $v = \frac{q}{f}$ $-dq = \frac{q}{fT}dt = \frac{q}{T}dt$ $-\frac{dq}{q} = \frac{dt}{T}$ $-\log_e q = \frac{t}{T} + K$ when $t = 0$ $q = Q$ $-\log_e Q = K$ $-\log_e q = \frac{t}{T} - \log_e Q$ $\log_e \frac{Q}{q} = \frac{t}{T}$	$c = \frac{q}{f}$ and $v = \frac{q}{f}$ $c = \frac{q}{f}$ $q = Q\varepsilon^{-\frac{t}{T}}$ $c = \frac{Q}{f}\varepsilon^{-\frac{t}{T}}$ $= C\varepsilon^{-\frac{t}{T}}$ $\frac{c}{C} = \varepsilon^{-\frac{t}{T}}$ $\frac{C}{c} = \varepsilon^{\frac{t}{T}}$ $\log_e \frac{C}{c} = \frac{t}{T}$
	$dQ = C\varepsilon^{-\frac{t}{T}}dt$ $\int dQ = C\int_0^\infty \varepsilon^{-\frac{t}{T}}dt$ $Q = CT$		$C = \frac{c}{f}$; $CT = \frac{c}{f} \times fT$; $cf_1 = Q$ $\therefore Q = CT$	
	$dT = vc\,dt$ $= rC^2\varepsilon^{-\frac{2t}{T}}dt$ $T = rC^2\int_0^\infty \varepsilon^{-\frac{2t}{T}}dt$ $= rC^2\frac{T}{2}$		$T = \int v\,dq = \int\frac{q}{f}dq = \frac{1}{f}\int_0^Q q\,dq$ $= \frac{1}{f}\frac{Q^2}{2} = \frac{1}{f}\times\frac{C^2T^2}{2} = \frac{1}{f}\frac{C^2fTr}{2}$ $= C^2r\frac{T}{2}$	

Test of the power of magnetic pulley no 3 3rd Dec: 1890.

Conditions of test the same as that already recorded on page 18.

No of Obs.	Ammeter	Obach	Current amperes	accepted current	Ampere turns	Load lbs.	distance inches	Moment ft. lbs.	Added	Total	Pull at axle
1	2	0·35	1·795	1·8	720	24·5	80	100	160	260	208
2	4	0·820	4·103	4·1	1640	"	76	152		412	250
3	6	1·14	5·848	5·85	2340	"	84	168		428	262
4	8	1·55	7·950	7·95	2780	"	93	186		446	277
5	10	1·89	9·694	9·69	3876	48	45	180		340	272
6	15	2·58	13·23	13·23	5292	"	51·5	206		366	293
7	19	3·40	17·44	17·44	6976	"	61	244		424	339
8	28	5·20	26·68	26·7	10,680	"	62	268		428	343
9	34	6·40	32·8	32·8	13,120	"	63	272		432	346

The curve is added to the sheet on p. 18.

Test of large 8" pulley 4th Dec: 1820 Weighing method.

No of Obs.	Ammeter	Obach	Current amperes	accepted current	Ampere turns	Load	Dist: Feet	Moment ft-lbs	Pull at axle	
1	2	0.335	1.72	1.72		41.5	8	332	266	
2	4	0.82	4.10	4.10		101.5	"	812	650	
3	6	1.21	6.21	6.21		121.5		972	778	
4	7	1.39	7.13	7.13		126.5		1012	810	
5	9	1.625	8.33	8.33		140		1120	896	
6	13	2.55	13.08	13.08		151.5		1212	970	

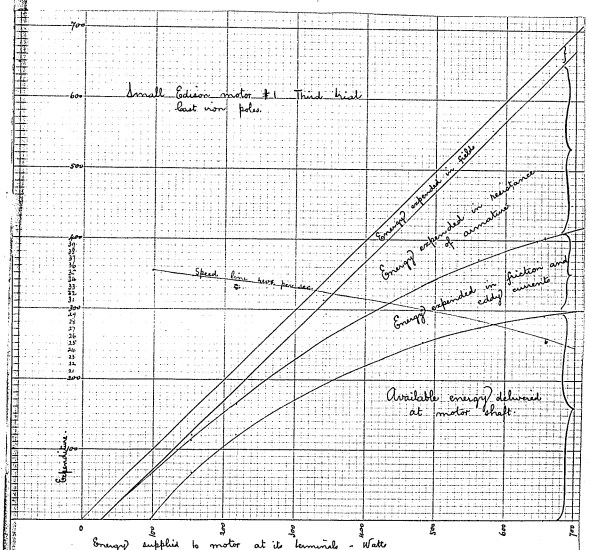
Test of Pulley no 3. after rewinding grooves in alternate directions.

No of Obs.	Ammeter	Obach	Current amperes	Ampere turns	Load	distance inches	Moment ft. lbs.	Added	Total	Pull at axle	
1	2		1·8	720	80	96	80	friction		64	
2	4	0·745	3·82	1528	19	"	152			122	
3	6	1·10	5·64	2256	26	"	208			166	
4	8	1·55	7·95	3180	30	"	240			192	
5	10	1·75	8·98	3592	31·5	"	252			202	
6	15	2·40	12·3	4920	35	"	280			224	
7	28	5·15	26·4	10560	48	"	384			307	
8	2	2 × 0·175	1·8	720	24	61	122	56	178	142	
9	4	0·35	3·59	1436	48	66	264		320	256	
10	6	0·57	5·85	2340	48	86	344		430	334	
11	8	0·72	7·38	2952	67	74·5	416		490·5	392	
12	10	1·02	10·46	4184	61	73	371		437	350	
13	27	2·35	24·1	9,640	109	70	566		622	497	

No. of Obs.	P.D. on motor	Bleach	Current in motor	Energy in motor	Energy in field	Energy in armt.	Calculated res. loss in armt.	Difference	Revs. per min.	Revs. per second	diff. in armt.	p.d. in armt.
1	122·0	0·067	0·24	29·3	29·3	-						
2	"	0·155	0·795	97·0		67·7	2·55	65·2	2926	35·4	8·46	117·4
3	"	0·250	1·292	156·1		126·8	9·02	117·8	2086	34·75	8·67	113·3
4	"	0·370	1·795	219.		189·7	20·06	169·6	1980	33·0	12·9	109·1
5	"	0·770	3·950	482.		452·7	114·6	338·1	1819	30·3	30·9	91·1
6	"	0·990	4·617	563.		533·7	159·3	374·4	1712	28·5	36·44	85·6
7	"	1·05	5·385	657.		627·3	220·2	407·1	1525	25·4	42·8	79·2
8	"	1·46	7·488	913·5		884·2	472·5	411·7	1043	17·4	65·2	56·8

Efficiency test of small motor with cast iron field poles. Continued from page 21. Same model.
December 3rd 1890.

S.M.J. per min. for sec.	Scale Reading	Torque cm. gms.	Energy delivered ergs	Energy lost in friction	Energy lost in res. of armt.	Total	Electrical Efficiency.	Mechanical Efficiency.	Conditions
-	-								Field only
3·326	{200 @ 25 / 200 @ 25}			65·2	2·5	67·7	0·672	-	Running light
3·260	{50 @ 45 / 200 @ 25}	3·175	68	49·8	9·0	126·8	0·755	0·436	Driving dynamo armt.
3·306	{50 @ 39·0 / 200 @ 20 / 1000 @ 10}	59·50	121	158·6	20·1	189·7	0·774	0·550	Driving - . Plus L.E. field
3·007	{50 @ 71 / 200 @ 18 / 1000 @ 10}	13,550	253	85·1	114·6	452·7	0·701	0·525	load of 1 amp
3·004	{50 @ 23 / 200 @ 20 / 1000 @ 10}	15,650	275	99·4	159·3	533·7	0·668	0·488	1·5 .
3·120	{50 @ 12 / 200 @ 10 / 1000 @ 20}	L.E. 600	294	116·1	220·2	627·3	0·620	0·463	1·9 .
3·265	{50 @ 15 / 200 @ 15 / 1000 @ 20}	24,075	280	131·7	472·5	884·2	0·451	0·307	3·1 .



On the equations of gramme ring motors with any number of poles, with the formulæ for determining the armature breadths.

Let r = the int: radius of core (cms)
R = " ext: " " " "
b = " breadth of core cms
n = " no: of turns made by armature per second
p = " no: of poles
w = " no: of wires counted all round the armature
D = " diameter of the covered wire (cms)
d = " " " " copper wire (")
a = " armature surface coefficient of reduction for winding
g = " covering coefficient $\frac{d}{D}$
$\mathfrak{o}$ = " length of one turn round the armature.
l = " number of layers
γ = " current density in the wire (amp: per sq: cms)
c = " current in the wire (amp.)
$\mathfrak{B}$ = " " " brushes or armature cct. (amp)
Q = " resistance of the whole ring
q = " resistance of the armature
λ = " coeff: of increase of armr res: for platinoid.
$\mathfrak{B}$ = " mean ~~coeff~~ induction density in the cross section of the core space
φ = " polar flux C.G.S.
e = " e.m.f. generated by the armature (volts)
E = " " " ~~transmitted at~~ " " terminals (volts)
h = " armature efficiency or e/E
t = " mechanical energy delivered by the shaft (Watts)
T = " " " absorbed by armature
m = " " efficiency of armature $= \frac{t}{T}$

$$T = EC = \frac{t}{h}\mathfrak{B}$$

$$t = mE\mathfrak{B} = \frac{mt\mathfrak{B}}{h}$$

$$e = \varphi n w \times 10^{-8}$$

$$\varphi = 2\mathfrak{B}(R-r)b$$

$$e = 2\mathfrak{B}(R-r)bnw \times 10^{-8}$$

$$D = \frac{2\pi r a l}{w}$$

$$d = \frac{2\pi r a g l}{w}$$

$$c = \gamma \frac{\pi}{4} \cdot \frac{4\pi^2 r^2 a^2 g^2 l^2}{w^2} = \frac{\gamma \pi^3 a^2 g^2 l^2 r^2}{w^2}$$

$$\mathfrak{B} = \frac{p\gamma\pi^3 a^2 g^2 l^2 r^2}{w^2}$$

$$t = \frac{m\varphi n w 10^{-8} \cdot p\gamma\pi^3 a^2 g^2 l^2 r^2}{h\, w^2}$$

$$t = \frac{2\mathfrak{B}(R-r)b\, m n\, p\gamma\pi^3 a^2 g^2 l^2 r^2 \cdot 10^{-8}}{hw}$$

$$a = \frac{w\,\mathfrak{o}\,\rho}{\frac{\pi}{4} d^2} = \frac{4 w^3 \mathfrak{o}\rho}{4\pi^2 a^2 g^2 l^2 r^2} = \frac{w^3 \mathfrak{o}\rho}{\pi^2 a^2 g^2 l^2 r^2}$$

$$q = \frac{w^3 \mathfrak{o}\rho\lambda}{p^2\pi^2 a^2 g^2 l^2 r^2}$$

$$\mathfrak{B} q = E(1-h)$$

$$q = \frac{E}{\mathfrak{B}}(1-h)$$

$$w^3 = \frac{E}{\mathfrak{B}}(1-h)\frac{p^2\pi^2 a^2 g^2 l^2 r^2}{\mathfrak{o}\rho\lambda}$$

$$w = \pi\sqrt[3]{\frac{E(1-h)p^2 a^2 g^2 l^2 r^2}{\mathfrak{B}\,\mathfrak{o}\rho\lambda}}$$

$$b = \frac{th\sqrt[3]{\frac{E(1-h)p^2 a^2 g^2 l^2 r^2}{\mathfrak{B}\,\mathfrak{o}\rho\lambda}}}{2\mathfrak{B}(R-r)\, m n\, p\gamma\pi^3 a^2 g^2 l^2 r^2 \cdot 10^{-8}}$$

$$= \frac{th\sqrt[3]{\frac{E(1-h)p^2 a^2 g^2 r^2}{\mathfrak{B}\,\mathfrak{o}\rho\lambda}}\, 10^{8}}{l^{\frac{5}{3}} 2\mathfrak{B}(R-r)\, m n\, p\gamma\pi^3 a^2 g^2 l^{\frac{4}{3}}}$$

$$= \frac{ht\sqrt[3]{\frac{E(1-h)p^2 a^2 r^2}{\mathfrak{B}\,\mathfrak{o}\rho\lambda}} \times 10^{\frac{8}{3}}}{2\pi^3 g^2 \times l^{\frac{5}{3}}\gamma\, \mathfrak{B}(R-r)\, m n\, p a^2 r^2}$$

$$b = \frac{100 \times 0.9 \sqrt[3]{\dfrac{110 \times 0.1 \times 0.25 \times 0.744 \times 4 \times 26.0}{1.4 \times 9 \times 1.8 \times 1.1}} \times 10^{+60}}{g^{2/3} l^{1/3} \times 2 \times 0.25 \times 0.744 \times 4 \times 26.0 \times 10{,}000 \times 500 \times 0.65 \times 30 \times 2 \times 9.86 \times 2.5}$$

$$= \frac{0.9 \sqrt[3]{\dfrac{11 \times 26}{11.2 \times 1.93}} \times 10^{5}}{g^{2/3} l^{1/3} \; 465 \times 0.65 \times 850 \times 9.86}$$

$$= \frac{1414}{g^{2/3} l^{1/3}}$$

If $g = 0.85$ $\quad g^{2/3} = 0.81$ $\quad b = 2{,}026/l^{1/3}$

If $l = 10$ $\quad l^{1/3} = 2.16$

$l = 2$ $\quad l^{1/3} = 2.5$

$l = 3$ $\quad l^{1/3} = 4.3$

$l = 4$ $\quad l^{1/3} = 6.35$

Electromagnetic design for a 100 = Watt Edison motor.

Retaining the same pattern as the ½ HP motor and with the same diameter of armature the formula for breadth becomes

$$b = \frac{th \sqrt[3]{\dfrac{E(1-h)\rho g \, 10^8}{C \, a^2 \rho \, b^2 \, f \, m \, n \, \pi \, R - r)}}}{g^{2/3} l^{1/3}}$$

$t = 100$ $\quad h = 0.9$ $\quad E = 110$ $\quad a = 0.5$ $\quad g = 0.85$ $\quad t = 5.1$ $\quad R = 7.6$ $\quad \rho = 2$ $\quad b = 10{,}000$

$a^2 = 0.25$ $\quad g^{2/3} = 0.7225$

$\rho = 1.8 \times 10^{-6}$ $\quad C = 1.4$ $\quad n = 30$ $\quad f = 500$ $\quad \sigma = 8$ $\quad \lambda = 1.1$ $\quad m = 0.65$

Hence, $b = \dfrac{16.4}{g^{2/3} l^{1/3}}$. Taking a trial value of g as 0.85

$b = 20.24/l^{1/3}$

For $l = 10$ $\quad b = 0.95$

With the same values $w = 960$ say 960

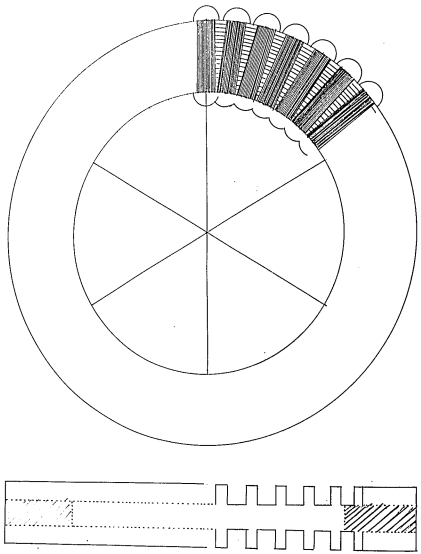
The induction-density in the core of the ½ HP model is 14,450. depth being 2.5, gives a flux of 72,250 lines per cm: of width of core. Taking 0.8 cm ($\frac{1}{3}$rd") we have a useful flux of 57,800 lines. With $n = 30$ $\quad gn = 1.7314 \times 10^6$ and to generate 110 volts the wires have to be 63.45. The winding breadth in the grooves, = 0.20" and 12 turns in this space = 0.0166" = 0.014" copper = # 28 B.W.G. The number of layers will be 14 = 168 wires in each groove = 42 feet = 5.5 × 10^12 = 2.3 ω per groove. The total res: = 96.6 ω, and the res: between brushes 24.2 ω. At full load of 1.5 amperes, the fall of potential will be 36 volts or 33%. This is perhaps excessive. # 27 B.W.G. the next size = 0.016" diam = 0.018" covered and 12 = 0.216 say 0.22" broad, while 14 = 0.252" high. The 42 feet = 1.8 ω hot per groove = 18.9 ω in the whole armature, with platinoid say 19.5 ω hot. The speed being 1500 per min: at no load will fall to 1300 on full load or 27%.

The flux to be supplied is 57,800 with leakage say 100,000. The density in the core is say 12,500 = 18 sq. cm. the ~~diam~~ of which = 3.89 sq. cms: ~~cmds~~ = 1¼". The reluctance of the circuit is 0.01 and to drive 60,000 lines through it requires 6000 A.M.T. = 4800 amp. turns. With 0.2 amp. this = 24,400 turns. With a mean turn of 0.5' feet this is 12,200' to have 550 ω = 22.2 feet per turn. = # 28 nearest.

550 ω of # 31 B.W.G. = 5335 feet = 10.670 turns = 2,314 A.T. = 1 lb. 10 oz.

To have 4800 A.T. @ 1.5 amp = 3200 turns series wound, and to lose 25 Watts in the machine at 2.0 amp = 12.5 volts drop = 6.25 ω. 1600 feet offering 6.25 ω. 256 ft per ω = # 18 B.W.G. 3 lbs. of wire offering 6.25 ω = 2.08 ω per lb. = # 20 B.W.G. = 810 feet = 3200 A.T.

Full depth elevation and plan of armature core.



Particulars of Maison 1/8th. HP. (1 watt delivery) Motor.

Weight without wooden base 20 1/2 lbs. 4
With wooden base 21 1/2 "
Winding gramme-ring, and series field.
Voltage 120 at machine terminals.
Amperes loaded to delivery of 1/8 HP. 1.5
running light 0.2
Commercial efficiency at delivery of 1/8 HP. 53 %
" " " " 1/6 HP. 49 %
Speed running light 2500 revs. per min.
at delivery of 1/8 HP. 2000 revs. per min.
Dimensions
Armature body diameter, external 6", internal 4"
Number of grooves 42
Breadth of armature body over teeth, 29/32"
" " " " at base of grooves 11/32"
Cross-section of armature core 2.18 sq. ins.
Depth of grooves 9/32", breadth 0.24"
Breadth of teeth 0.21" at external, 0.09" at internal wire.
Insulation in grooves 0.008" mica at sides and oiled silk at base
Polar surface of teeth 20 sq. cms. under each pole.
Winding 420 turns, 14 layers of 10 turns each of # 27 BWG.
0.015" covered to 0.0225"
Thickness of iron strip forming core 0.030"
Commutator divisions 42.
Total length of wire on armature 1500'
Total weight " " " " 1.15 lbs.
Flat gold wire from armature to commutator
Length 2 1/2" Diameter 0.006" Resistance 1.75 ohms each.
Resistance of armature between brushes cool (incl. platinoid)
hot " " 17.75 ohms
Current in armature at full load 1.5 amperes.
Drop in armature " " 26.6 volts.
Energy expended in heating armature wire at this load 40 watts.
Magnetic flux through armature section 30,000 CGS. lines.
Induction density in core space (iron and paper) 13,700 per sq. cm.
Field magnet, of mitis cast wrought iron. Pole pieces of wrought iron in 8 segments
Core diameter 1.4" Inharflance 4".
Diameter over wire 2.28", over cover 2.33
Flux through core center at full load 120,000 CGS. lines.
Induction density in core at full load 12,120 lines per sq. cm.
Winding 450 turns of wire, 8 layers.
Wire 0.049" # 18 BWG, covered to 0.065"
Ampere-turns at light load 135, at full load 675.
Resistance of field winding 1.0 ohm cool 1.2 ohm hot.
Drop in field at full load 1.8 volts.
Energy expended in heating field wire at full load 2.8 watts
Total resistance of motor between terminals 2½ cool [illegible] hot.
Brushes of copper gauze [illegible]
Line wire safety catch 0.016" fuse at 3 amp

Electromagnetic design for a small 100-Watt Edison motor.

Power 100 Watts 110 volts - 2 amperes maximum current.

42 grooves Each {0.7" deep / 0.24" wide} and {0.7" wide / 0.24" deep} Total breadth 29/32" 2.25

42 Commutator bars.

Armature wire #27 B.W.G. 0.016" Paper covered to 0.018".

12 wires in each layer = 0.216" insulation 0.024".

14 layers = 0.252" insulation 0.008".

168 wire per groove = 7056 wires all round. (5460 actually placed)

Breadth of core proper 0.87 cm (17/32") Allowing 14,450 lines per sq. cm gives 62,850 lines usefully developed. Cross section 2.18 sq. cms.

Speed 30 revs. per sec. = 1800 per mins. = 2830' per min. at periphery

Surface of side of armature 15.7 sq. in. = 101.3 sq. cms, to each segment 2.141 sq. cm. of which 1.75 is occupied by grooves leaving 0.66 sq. cm. per groove of iron, and 17 grooves will be covered by pole leaving 11 sq. cms. of iron on each side = 22 sq. cms of surface iron offered to the poles.

Clearance 7/32" (0.08). Reluctance in air $\frac{2 \times 0.08}{22}$ = 0.0072

6 cms. of iron @ 14,450 .0060

Reluctance of armature 0.0132

Mean length of one turn on the armature 9.5 cms. = 0.31 ft.

Total length of wire 2187' = 7.75×10^{-4} lbs. per ft. = 1.69 lbs. of wire

Total res. of wire 2187 × 0.016 = 22 ω

The next size of wire = 0.018" #26 B.W.G. covered to 0.020" gives 11 wires in one layer, and for depth 12 deep = 132 wires per groove or 5544 wires in all. The weight would be 1.75 lbs.

The length 5544 × 0.31 = 1720' ≈

The res. 1720 × 0.032 ÷ 4 = 13.7 ω cool or 16 ω hot.

The speed for 105 volts would be $\frac{105}{5.544 \times 6285}$ = 30.1

The winding adopted was 130 turns per groove (13 layers of 10 turns each) #(22–27) B.W.G. 0.0153 single cotton covered to 0.0225. The resistance of each section is 1.6 ω cool. The base in the grooves is of oiled silk, and the walls are lined with mica.

The field magnet 1¼ diameter, is wound with 6 layers of 39 turns of #14 B.W.G. cost to or 234 turns in all.

The resistance of the armature cool between brushes is 14.95 ω. including the 3½" length of platinoid

For the determination of the wire on the field magnet see p 50.

The diameter of the core in the white iron pattern is 3.55 q.q.q.m

polar uprights are 2.54 × 1.85

Interflange 10.2.

The weight of the wooden pattern is 7 oz or 199 gm

The platinoid connecting wire were 3" long fuse of 0.011" 0.55 ω

meat " 0.0073" 1.2 ω

thick " 0.0056" 1.6 ω

Inductance of the secondary of the large induction-coil by the method of discharge. 5th December 1920.

Source of EMF	Capacity	a	Mean throw	q per div.	
1 C.C. @ 20°C + 2 ϕ 1.4325 × 10⁸	2.0 ϕ × 10⁻¹¹	2.865 × 10⁻⁷	24.1.5	1.187 × 10⁻⁹	

E.M.F.	Res: of discharge circuit	Current abs. m.	Res: in cells with q plots	Total res: of circuit	Max. potential throw of G.	q.	Throw	Inductance abs.	Legal Henrys	True Henrys
3.20	30,600 Ω legal	1.046 × 10⁻⁵	100,000 Ω	138,880 Ω (1.385 × 10⁵)	127	1.507 × 10⁷	2.048 × 10⁷	1.958 × 10¹⁰	1958 H	1970 H
			25,000 Ω	60,850 Ω (6.085 × 10⁴)	278	3.30 × 10⁷	2.008 × 10⁷	1.920 × 10¹⁰	1920 H.	1932 H.

Cardew voltmeter observations made by Mr Davis in timing freezing with the Westinghouse Dynamo.
Book of Nov. 20.

No. of Obs.	Position of Switch	Res. in cells	Obs.	Res. of Switch & Obs.	Total res.	Multiplying factor	Volts at Switch	Result		Mean	r.
1	Main Dynamo	7500	56	294	7794	2645	58.0	1538	86,120		
2		7000	65	297	7297	24.57	63.0	1548	101,600		
3		6000	90	306	6306	20.6	74.5	1536	138,250		
4		4000	165	340	4340	12.77	108.0	1380? 2nd	324,970	1540	± 2.5
1	Excitation Chamber	7500	60	295	7795	26.43	60.0	1586	95,160		
2		7000	72	300	7300	24.33	66.0	1606	115,650		
3		6000	90	306	6306	20.61	74.5	1536	138,250		
4		4000	212	360	4360	12.11	130	1575	333,800		
			434						682,860	1574	± 15

The Weights given to the individual observations are the observed no. of degrees

On the Inductance of Large Edison Field Magnets.

No. of Standard Magnet	Wires all round mm.	Res: per sec: at 120 v.	Calculated q	Total q allowing for leakage for 1.8	Weight of wire + bags on each magnet	Mean circumference	Total length on each magnet	No. of turns on both magnets	Res: of magnets (cold) at no load	Current in magnets	Flux × Turns in ampères per ampère
60	16.4	6.4	1.14 × 10⁷	1.71 × 10⁷	405 lbs + 8 lbs.	6'	4.860	1620	17.2	7.0	4 × 10⁹
C Mean	800	11.7	1.292 × 10⁷	1.923 × 10⁷	113 lbs + 22 lbs + 115 lbs + 30	4.8'	68,250'	27,800	24.00	0.574	9.37 × 10¹¹
Edis. S.C. 41											17.4 × 10³

Iron wire used experimentally in circuit with a cautery battery = 625 cms: of 0.079" diam: galvanized #14 B.W.G.

Using this wire in a spiral of 64 turns, the current from the battery of 8 cells was 35 ampères with the res: all out, or 0.174 ω of which 0.014 was in leads leaving 0.160 ω or 0.02 ω p. cell.

With the resistance all in, the current fell to 9.5 ampères = 0.63 ω or 0.46 ω in the iron wire. This range appears to be sufficient.

The weight of this battery of 8 cells fully charged is 12½ lbs.

Insulators of rubber tube, were put on the copper guides on the 22nd Jan.

The total length of wire on the field magnet is 559 × 9.687 = 5415

diam. of the core is 1.875"

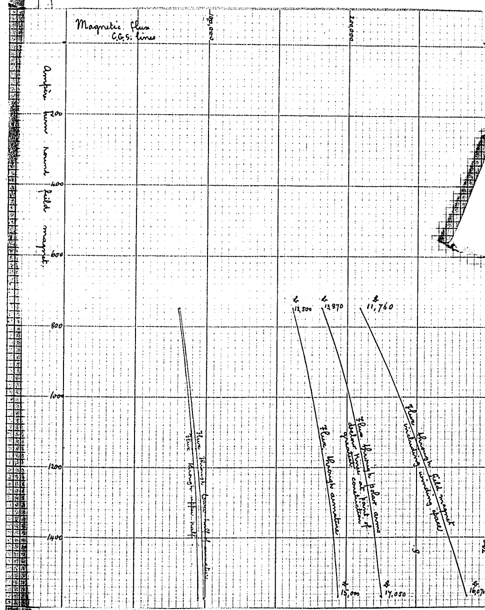
wound core. 3.55"

Mean diam 2.713"

Mean circum 8.5" = 0.71' = 7630 turns

No. of Obs. | 1

No. of Obs. | Sl | 1 | 2



Magnetic measurements with the small ½ HP motor
8th December 1890.

5 turns of insulated wire were wound upon (1) the centre of the field-magnet (2) upon the polar arcs just below the turns (3) upon the armature between the poles both above and below, these forming independent secondary coils

Source of EMF	E.M.F.	Capy.	a	Mean throw	q per div.
1 C.C. @ 14°C	1.439×10^{8}	2.00×10^{-11}	2.878×10^{-7}	233	1.235×10^{-7}

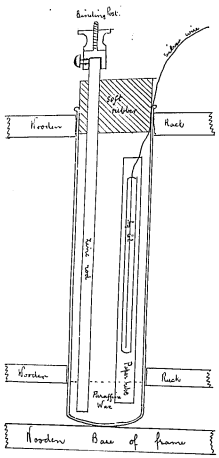
Field Amp.	Turns	Current amp.	Estimated Amp. turns on field	No. of throw & position		Mean throw	Res. of field & G. ckt.	Res. of G. ckt.	q	φ	L
15·0	0.2679	0.206	1570	Field Magnet	3	227	5000	10,200	2.803×10^{-8}	2.86×10^{-8}	16,070
				Leg. 1	3	88	-	-			
				- 2	4	89.4	-	-		1.12 -	17,050
				- 3	4	88	-	-	1.125	1.126 -	
				- 4	3	89.7	-	-		1.058 -	
				Upper arm	3	75.2	-	-		1.130 -	
				Lower	3	78.5	-	-		0.3474 -	14,690
										0.3880 -	15,340
11·0	0.1944	0.150	1144	F. Magnet	5	199	-	-		2.507 -	14,090
				Leg. 1	4	84	-	-		1.058 -	16,030
				- 2	4	83	-	-			
				- 3	4	79	-	-	1.058	1.045 -	
				- 4	3	84.8	-	-		0.305 -	
				Upper arm	4	71.5	-	-		1.068 -	
				Lower	4	73.5	-	-		0.906 -	13,970
7·15	0.1272	0.098	750	F. Mag	4	166	-	-		0.926 -	14,360
				Leg 1	3	72.7	-	-		2.092 -	11,760
				- 2	4	70.5	"	-		0.915 -	13,870
				- 3	3	67	-	-	0.900	0.891 -	
				- 4	3	73	-	-		0.844 -	
				Upper arm	3	63.7	-	-		0.920 -	
				Lower	3	64.3	-	-		0.802 -	12,440
										0.810 -	12,560

The cross section of the field magnet is taken at 17·8 sq. cms.
- - - - - - pole - - - 6·6 - - at the
point of greatest constriction
- - - - - armature core space - 6·45 - -

Test of pulley no 2 rewound in reverse directions alternately.
55 turns in each groove = 275 turns in all. 8. XII. 90

Run No.	Turns	Shoes	Current	Amp. turns	Balance Stopping Weight	Distance	Moment ft lbs.	Equivalent pull at one rope	Total allow. 12% for friction
1	2	0.35	1.823	501	58 lbs	8'	144	115.2	243
2	4	0.83	4.323	1188	26		208	166.4	294
3	6	1.13	5.885	1618	35		280	224	352
4	8	1.32	7.92	2178	38		304	243.2	371
5	10	1.85	9.636	2650	41		328	262.4	390
6	12	2.075	10.81	2973	45.5		364	291.2	419
7	14	2.3	11.98	3294	49		392	313.6	441
8	16	2.5	13.02	3580	57		456	364.8	492
9		5.5	28.65	7780	60		480	384	582

The curve is added to the sheet on page 18



Full sized vertical section of cell.

Table of Inductances of Copper wire suspended overhead

Calculated from the formula $l = (2 \log_e \frac{4h}{d} + 0.5)$
where h is the height above the ground, d the diameter, and l the inductance per cm.

Diameter of copper		Suspended 400 cm or 13 ft above ground		Suspended 900 cm or 29 ft above ground		Suspended 1000 cm or 32.8 ft above ground		Suspended 1300 cm or 42.65 ft above ground	
cm	Inches	Millihenrys per kilometre	Microhenrys per mile	Millihenrys per kilometre	Microhenrys per mile	Millihenrys per kilometre	Microhenrys per mile	Millihenrys per kilometre	Microhenrys per mile
0.10	0.039	1.986	3.196	2.109	3.393	2.170	3.493	2.222	3.576
0.20	0.079	1.848	2.974	1.960	3.154	2.031	3.268	2.083	3.352
0.30	0.118	1.766	2.842	1.878	3.022	1.950	3.138	2.002	3.222
0.40	0.158	1.709	2.750	1.821	2.930	1.892	3.045	1.945	3.130
0.5	0.197	1.664	2.678	1.776	2.858	1.847	2.973	1.900	3.058
0.6	0.236	1.628	2.621	1.740	2.800	1.811	2.914	1.863	2.998
0.7	0.276	1.596	2.569	1.709	2.750	1.780	2.865	1.833	2.950
0.8	0.315	1.570	2.527	1.682	2.706	1.754	2.823	1.806	2.906
0.9	0.3544	1.547	2.489	1.659	2.669	1.730	2.785	1.783	2.870
1.0	0.394	1.526	2.456	1.638	2.635	1.709	2.750	1.761	2.834

Tests and data of the new model Edison Silver-Chloride cells.

10th Dec. 20.

5 oz. of Ag Cl. were melted, and 10 plates were cast in glass tube ¾ diam. The total weight of castings with silver wires being 64.5 gms. The weights of the different parts of the cell are:-

Glass tube	30 grammes
Rubber stopper	16.8 "
Zinc rod	15.5 "
Binding post	7.0 "
Ag + AgCl plates	7.5 "
	76.8
Solution	40
Weight of one cell complete	116.8

The weight of a sample was 124.5 g.

The E.M.F. of the battery of 10 cells was	10.13 volts		1.013 p.c.
internal res.	168 ω		16.8 "
E.M.F. of the first 5 cells was	5.13		1.026 "
internal res.	62 ω		12.4 ω "
E.M.F. " second "	5.0		1.00 "
internal res.	105 ω		21 ω p.c.

Particulars of different ½ H.P. motors by various manufacturers

No. of Motor	Maker.	Date of Price List	Weight	Speed.	Pulley diam.	Pulley face	Floor space	List Price	Discount
1	Edison M.W.	1889	130	1900	2 7/16"	2"	20 × 17 3/4	$ 130	
2	Burnell & Co	11th Mar 20	–	–	–	–	–	$ 130	25 + 20
3	J.B.C. Co	1820	–	–	–	–	–	$ 130	
4	Connecticut	1820	150	2000	3½"	2	11½ × 17	$ 130	
5	Daft	Mar 1820	85	2,900	3	2	16 × 12	$ 140	
6	Eddy	1889	142	2,100	3½	2¼	–	$ 130	
7	N.Y.E. Mfg Co	1820	–	–	–	–	–	$ 130	90%
8	Perrit	1889	70	2000	2½	1½		$ 130	
9	Ritter	1889	–	2400	3	2		$ 120	
10	Detroit	1890	114	2200	3	2		$ 130	
11	Edison	1890	36	$ 1750	2¼	1½"	7" × 8½"		

Magnetic experiments with a permanent magnet.

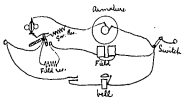
A horse shoe magnet, of the dimensions shewn was made of tool-steel. Upon its extremities shoes were forced carrying two disks facing each other on arms sliding through the shoes.

Experiment no 1. The magnet was wound with 320 turns of # 12 B.W.G. the disks brought into contact, the magnet excited with perhaps 50 ampères, for about 1 minute, and the residual magnetism then tested by separating, and uniting the two disks while the induced current through the wire was observed on the ballistic galvanometer

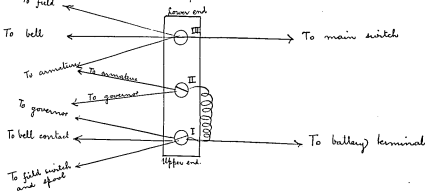
No. of Obs.	Source of EMF	E.M.F. + Corr	q.	Mean throw	q. per div.
6	1 G.G. @ 15°C	1·438 2[9]	$2\cdot976\times10^{-7}$	231·5	$1\cdot242\times10^{-9}$

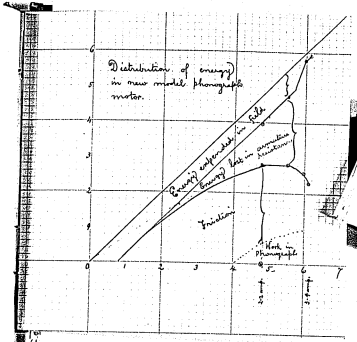
No. of Obs.	Res. in cct. with G	Res. of G. cab.	Mean Throw (by opening & closing magnet)	q	φ	Section of magnet sq. cm.	L.			
7	0	8200	64	$7\cdot952\times10^{-9}$	$\frac{4\cdot135\times10^{11}}{320} = 1\cdot29\times10^{8}$	1·98	65			

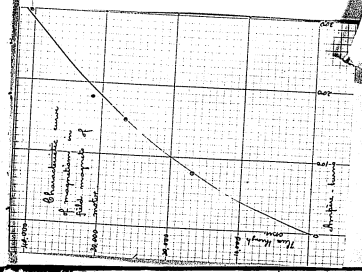
Diagram of Connections



Reversed view of Switchboard.







Electrical Data of New model Battery Phonograph.

The new model has a cast iron field magnet, but the same model of armature as heretofore. The weight of the whole machine is 44 lbs. It has a bell added to it, and it varies its speed from 50 to 230 revolutions by the governor and a resistance coil in the field magnet circuit.

The particulars of the various parts are as follow:-

Resistance of leads from battery		0.02 ω
- - 4 field coils in series		5.67 ω 3.185
- - field resistance spool german silver		10.14 ω
- - armature		
- - german silver shunt on governor		2.485 ω
- - bell		2.33 ω
Inductance of bell	4.051 ω 0.286 ℓ	= 11.4 h.
- - field	17.757 ω 3.58 ℓ	= 0.636 H

The following measurement was made of the magnetic flux through the field:- 18 turns of secondary round the center of one field.

No. of Obs.	Current through Obach	Current	Field (3.71) A.T. on 2 coils	Mean throw	Resistance of G. Inc. ext.	R. of G.	Value of 1 div: q_1	$\frac{q}{10}$	$\frac{q}{\sqrt{10}}$	$\mathcal{L}$
1	0.100	0.522	300	62.25	0	5250	1.242×10^{-3}	7.73×10^{-3}	40,570	5,070
2	0.060	0.313	180	48	-	-		5.96 -	31,300	3,815
3	0.050	0.261	150	41	-	-		5.09 -	26,700	3,340
4	0.026	0.136	78	26	-	-		3.23 -	16,960	2,120

When running at full normal speed the armature makes 3.75 revs: per second with a current of 2.4 ampères through it reducing the pressure by 0.8 volt, while the terminal p.d. was 2.0 volts so then

$$3.75 \times 108 \times q = 1.2 \times 10^8$$

$$q = \frac{1.2 \times 10^8}{405} = 30,000 \text{ approximately.}$$

No. of Obs.	Revs: of Armature	Work.	Obach	Current amperes	R.D. at M.T. volt	Energy absorbed	Resistance in fields	Energy absorbed in fields	Current in armature	disp. in armature	Utilisable energy
1	50	nil	0.425	2.218	2.140	4.75	0.378	0.809	1.840	0.64	2.82
2	144	-	0.520	2.713	2.052	5.57	0.362	0.763	2.351	0.78	2.82
	230	-	0.620	3.236	1.844	5.97	0.317	0.216	3.688	1.04	2.60
	-	respondwing	0.65	3.390	1.80	6.11	0.314	1.205	3.276	1.09	2.33.

Electrical Measurement of Power absorbed by the operation of a magnetic belt. 10th & December 1st 20.

A no. 4 motor was belted to a pulley on the same shaft as the magnetic pulley 8" in diam. whose behavior is given on page 23. One belt rested on this and passed over a large 23" diam: magnetic pulley fairly tight.

At 204 revs. per min: of 23" pulley: 1280' per min the Sprague motor took 26.56 amperes at 52 volts = 1380 Watts

At 280 revs. per min: = 1758' per min: the motor took 70.8 amperes at 69 volts = 4885 Watts when the small magnetic pulley was excited, a difference of 3505 Watts @ 75% efficiency = 2630 Watts lost in magnetic friction.

By a lever test, the moment of magnetic and mechanical friction required to move the magnetized small pulley was 28 foot x lbs.

On the 11th December. the experiment was repeated with small 4½" pulley from Schenectady which was wound right and left alternately, used in conjunction with a large magnetic pulley. The energy absorbed in magnetic friction over and above mechanical friction when running at 900 feet per minute was 1000 Watts with the belt fairly tight
1500 " " half cir: loose
2000 " " 5/16th contact loose.

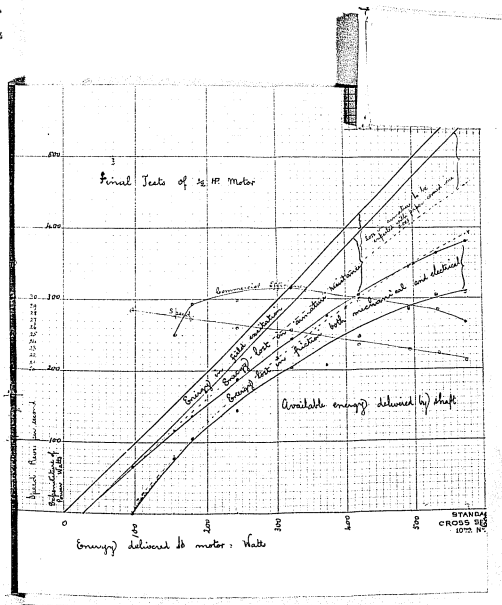
Test of a sprocket chain having link pins 3/32" diameter.
#4 motor driving, and absorbing 70 amperes @ 120 volts = 8400 watts
Prony break 450 revs p.m. 15 lbs: wt at 8 feet radius
50.27 x 7.5 x 15 x 0.737 = 7670 Watts
The pull upon the belt running on a 12" pulley = 240 lbs.

Test of the breaking stress of 1" 3=strand Rawhide rope.
40 spring 37.5 lbs: indicated. Piston area 77.06 = 2890 + weight of piston (100) = 2990 say 3000 lbs. weight.

Test No.	P.D. on motor	Ohmch	Current in motor	Energy in motor	Current in field	Energy in field	Current in armt	Energy in armt	Eff	Loss of energy armt	Volts field of motor	Energy in field	Energy available at shaft in watts	P.D. across lamp
1	122.5	0.163	0.224	27.4	0.224	27.4	0.089	-						
2	"	0.150	0.783	96.0	.	.	0.559	68.5	0.312	2.6	4.65		65.9	117.64
3	.	0.243	1.252	153.4	.	.	1.028	125.9	1.057	8.8	8.56		117.1	112.94
4	.	0.278	1.451	177.8	.	.	1.227	150.3	1.506	12.5	10.22		137.8	110.88
5	.	0.378	1.973	241.7	.	.	1.749	214.3	3.059	25.5	14.57		188.8	107.93
6	.	0.498	2.600	318.5	.	.	2.376	291.1	5.645	47.0	19.79		244.1	102.57
7	.	0.580	3.027	370.8	.	.	2.803	343.4	7.857	65.5	23.35		277.9	99.15
8	.	0.655	3.418	418.8	.	.	3.194	391.3	10.202	85.0	26.61		306.3	95.89
9	.	0.769	4.012	491.5	.	.	3.788	464.0	14.369	119.5	31.56		344.5	90.94
10	.	0.832	4.342	532.	.	.	4.118	504.5	16.958	141.3	34.31		363.2	87.19
11	.	0.900	4.697	575.4	.	.	4.473	548.0	20.008	167.3	37.26		380.7	84.24
12	.	0.870	4.540	556.2	.	.	4.316	528.8	18.628	155.2	35.96		373.6	86.56
			31.4	1.5			34.13	7						

Weight of Motor complete 36 lbs. = 72 lbs. per H.P. = 100lbs per knot.
Power with present winding 200 Watts @ 200 Watts intake = 66% eff.
300 . @ 500 . . = 60% .
expected with paper cond wire 300 . @ 420 . . . 70% .
400 . @ 600 . . . 66% .
expended in the field magnet 30 Watts
. . friction 40 to 65 Watts.
Armature unwound weight 6 lbs. Weight wound 8 lbs.
42 sections, each 49 turns 7 layer of 7 turns of # 26 BWG
0.018" d.c.c. to 0.029". With paper covered wire # 23 BWG.
0.025" covered . 0.028". Present res: warm including platinoid wire 8.83 ω. Paper cond. wire 4.33 ω.
Cross section of core 1" × 1". Grooves 0.225" broad and 0.225" deep
Field magnet. Diameter 1 7/8" wrought iron. Wound with
3 lbs: of # 31 BWG. 0.010" Res. 550 ω. = 1.7 lbs. of copper wire.
Res: warm 600 ω.
Speed 1780 revs. per min running light
1300 . . . . at full load.

Flux through field magnet 250,000 = 16,000 per sq. cm.
. . wrought iron polar extensions 225,000 = 17,000 per sq. cm.
. . armature 190,000 = 15,000 per sq. cm. through core space.



Final Test of the Edison ½ H.P. motor before sending off the model

11th December 1820 Res. of arm: 8.33.

Revs: per min.	Revs: per second	E.M.F. per sec.	Scale	Reading	Torque	Energy delivered 6165	Energy in Gallons	Ht & Ht. eff. %	Mech. eff. %	Remarks.
–			–		–	–				Current in field
1710	28.5	4.13		–	–	–	65.9	68.6	50.6	Motor running light
1660	27.67	4.08	200 @ 20 25 @ 11		4550	77.6	39.5	76.3	50.6	Driving dynamo light
1640	27.33	4.07	500 @ 10 50 @ 13.5		6175	104.1	33.7	77.5	58.55	– dyn. arm. thru s.c. field
1558	25.97	4.16	500 @ 15 200 @ 5 50 @ 8.2		8910	142.7	46.1	78.14	59.03	1 lt. lamp on dynamo
1537	25.61	4.00	500 @ 20 200 @ 10 50 @ 16.7		12,835	202.6	41.5	76.65	63.60	2 - - - - -
1430	23.83	4.16	1000 @ 10 200 @ 20 50 @ 7		14,150	207.9	70.0	74.96	56.07	3 - - - - -
1410	23.50	4.08	1000 @ 20 200 @ 5 50 @ 8.5		17,150	248.5	57.8	73.14	59.34	4 - - - - -
1370	22.83	3.98	1000 @ 20 200 @ 5 50 @ 8.5		20,165	283.9	60.6	70.1	57.8	5 - - - - -
1330	22.17	3.93	1000 @ 20 200 @ 5 50 @ 8.5		22,200	303.5	59.9	68.26	57.1	6 - - - - -
1275	21.25	3.99	1000 @ 20 200 @ 10 50 @ 8.5		23,425	307.0	73.7	66.16	53.35	7 - - - 9.30 ends
1325	22.08	3.92	1000 @ 20 200 @ 10 50 @ 8.5		22,810	310.5	63.1	67.20	55.84	7 - - - Noon.

The temperature of the armature at noon was about 125° F.

The wire on this armature is 0.018" covered to 0.029". D.C.C.
allowing 0.028" and 0.003 for paper covering gives 0.025" or
23 B.W.G. which has 625 c. mils instead of 324. The res. of the
armature would be 4.33 instead of 8.33.

Required the best winding for an osc-milling analysis magnet for Mr Batchelor, to use with a Leclanche battery of 4 cells.

The core is to be 6" long (5·75" or 14·6) between flanges, and 1⅛" (3·18) in diam. The external diameter to be 2·75" (7). The current to be 3 amperes, and the emf. $(4 \times 0{\cdot}75 - 3 \times 4 \times 0{\cdot}084) = 2{\cdot}5$ volts so that the resistance is to be 0·83 ω.

$$d + t = 0{\cdot}0392 \sqrt[4]{\frac{R}{T}}$$

The coiling space is $14{\cdot}6\,(38{\cdot}5 - 7{\cdot}94) = 14{\cdot}6 \times 30{\cdot}56 = 44{\cdot}62$

$$= 0{\cdot}0392 \sqrt[4]{\frac{44{\cdot}62}{0{\cdot}83} \times 10^3}$$

$$= 0{\cdot}0392 \sqrt[4]{5376}$$

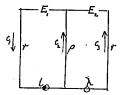
$$= 0{\cdot}0392 \times 8{\cdot}56$$

$$= 0{\cdot}3356 \text{ cms diam} = 0{\cdot}132'' \text{ less } 0{\cdot}015 = 0{\cdot}118''$$

$$= \#\ 11 \text{ B.W.G.}$$

This has a resistance of 0·01⅞ ω per lb. and for 0·83 ω, 44·88 lbs. will be required. Say 3 lbs.

On the solution of problems in 3-wire distribution



The equations of motion may be written

$$E_1 + E_2 - c_1(r+l) - c_3(r+\lambda) = 0$$
$$E_1 - c_1(r+l) - c_2(\rho) = 0$$
$$c_1 - c_2 - c_3 = 0$$

Or in determinant form

c_1	c_2	c_3		
$-(r+l)$	-0	$-(r+\lambda)$	$=$	$E_1 + E_2$
$-(r+l)$	$-\rho$	0	$=$	E_1
1	-1	-1	$=$	0

$$\therefore\ c_1 = \frac{(E_1+E_2)\rho \cancel{+ (E_1+E_2)(r+\lambda)}}{-\rho(r+l) \cancel{+ (r+l)(r+\lambda)} \cancel{+ \rho(r+\lambda)}} = -\frac{E_1(\rho + r + \lambda) + E_2\rho}{\rho(2r+l+\lambda) + (r+l)(r+\lambda)}$$

$$c_2 = \frac{E_1(r+l) + E_1(r+\lambda) \cancel{+ (E_1+E_2)(r+l)}}{\rho(2r+l+\lambda) + (r+l)(r+\lambda)} = -\frac{E_1(r+\lambda) - E_2(r+l)}{\rho(2r+l+\lambda) + (r+l)(r+\lambda)}$$

$$c_3 = \frac{(E_1+E_2)(r+l) + \rho(E_1+E_2) - E_1(r+l)}{\rho(2r+l+\lambda) + (r+l)(r+\lambda)} = -\frac{E_1\rho + E_2(r+l+\rho)}{\rho(2r+l+\lambda) + (r+l)(r+\lambda)}$$

Let $E_1 = E_2 = 125$ $\quad r = 0{\cdot}025$ $\quad l = 0{\cdot}1$ $\quad \lambda = 0{\cdot}111$ $\quad \rho = 0{\cdot}05$

Then

$$c_1 = \frac{125\,(0{\cdot}136)}{0{\cdot}05 \times 0{\cdot}261 + 0{\cdot}125 \times 0{\cdot}136} = \frac{17 + 12{\cdot}5}{0{\cdot}01305 + 0{\cdot}017} = \frac{29{\cdot}5}{0{\cdot}03005} = 982{\cdot}8$$

$$c_2 = \frac{125\,(0{\cdot}011)}{0{\cdot}05 \times 0{\cdot}261 + 0{\cdot}125 \times 0{\cdot}136} = \frac{1{\cdot}375}{0{\cdot}03005} = 45{\cdot}8$$

$$c_3 = \frac{125\,(0{\cdot}125)}{0{\cdot}05 \times 0{\cdot}261 + 0{\cdot}125 \times 0{\cdot}136} = \frac{15{\cdot}625 + 12{\cdot}5}{0{\cdot}03005} = \frac{28{\cdot}125}{0{\cdot}03005} = 936{\cdot}0$$

The pressure on l = 98·18 and on λ = 104·0

loss in r_1 = 24·54 in r_2 = 23·40 in ρ 2·29

On the activity of the average human being.

The amount of carbon administered to the average adult male daily is 4500 grains, according to the statement in the "Chemistry of Common Life". This is 0·7 lb and = 318 grammes. The heat energy of combustion of one grammes of carbon with oxygen forming CO_2 is 3.36×10^{11} ergs, so that the heat energy absorbed daily is 1068×10^{11} ergs or 1068×10^{7} joules. The number of seconds in one day is 8.64×10^{4} so that the average rate of absorbing power is $\frac{10.68 \times 10^{6}}{8.64 \times 10^{4}}$ = 123·6 Watts. during 10 hrs, or 307 Watts in

The average rate of working is stated to be 73·7 Watts, and the total work stated to be done by a labourer daily is 2.65×10^{6} joules. This represents a total commercial efficiency of 0·248. Of the carbon taken in 201·6 gms are said to be exhaled through the lungs daily or 739·3 - of CO_2 this represent a work of 6.77×10^{6} joules.

Tests of a sample of hard drawn copper wire for The Engineering Department.

This sample was received on the 13th December, was #4 B.W.G. and about 150 feet in length. The following measurements were made of its diameter, at points 3' apart in a length of 72 feet.

Number of Obs.	Diameter Inches.	Mean	v	v^2	Result	Cms.
1	0·2380"		0·0003	9×10^{-8}		
2	0·2376		0·0001	1		
3	0·2376		0·0001	1		
4	0·2373		0·0004	16		
5	0·2377		0·00			
6	0·2376		0·0001	1		
7	0·2374		0·0003	9		
8	0·2379		0·0002	4		
9	0·2378		0·0001	1		
10	0·2379		0·0002	4		
11	0·2380		0·0003	9		
12	0·2377		0·			
13	0·2379	0·2377	0·0002	4	0·2377 ± 0·00003	0·6038
14	0·2379		0·0002	4		
15	0·2379		0·0002	4		0·2844 sq. cms.
16	0·2378		0·0001	1		
17	0·2378		0·0001	1		
18	0·2379		0·0002	4		
19	0·2377		0·			
20	0·2377		0·			
21	0·2376		0·0001	1		
22	0·2378		0·0001	1		
23	0·2376		0·0001	1		
24	0·2377		0·			
25	0·2376		0·0001	1		
	18			77×10^{-8}		
	4·2736					

122. one of this wire weighed in air 308·235 gms. = 2·526 gms per cm. = 40660 gms per mile = 89·62 lbs. per mile. Sp.g. 8·42

$$\frac{2693 + 1150}{2707} = \frac{3843}{2707} = 1.427$$

$$\frac{2693 + 624}{2707} = \frac{3317}{2707} = 1.2255$$

$$\frac{2693}{2707 + 1155} = \frac{2693}{3862} = 0.6974$$

$$\frac{2693 + 130}{2707} = \frac{2823}{2707} = 1.043$$

$$\frac{2693 + 355}{2693} = \frac{3062}{2693} = +1.137$$

$0.00388 \times 22.2 = 0.08612$ Foot. $1598 \times 1.08612 = 1735.3$

Test of Sample Hard drawn Copper Trolley wire contd.

Five lengths of wire were measured off for a test of the conductivity, in two trials as follows:-

No. of Obs.	Point	1st Obs.	2nd Obs.	Mean	Length of section tested	Section Number	Length	
1	1	302.7	302.8	302.75	1944.4	1	2247.15	
2	2	590.0	590.1	590.05	1657.1	2	1944.4	
3	3	854.5	854.5	854.5	1392.65	3	1657.1	
4	4	1139.	1139.	1139.0	1108.15	4	1392.65	
5	5	2065	2014.7	2014.9	232.25	5	1108.15	
6	6	2247.2	2247.1	2247.15	-	6	232.25	
				7146.35 4901.2	6334.55 1335.08 4900.53			

Conductivity Test Res: of A.B. 2707ω std. + 2693ω wire per coil.

No. of Obs.	Length of wire tested	Standard.	Res: at temp:	Res: added	Ratio	Res: of wire	Res: per c.c. std	Mean Resistivity
1	2247.15	0.01ω	22°c.	1150ω Wire	1.427	0.00129576	1.779	
2	1944.4	0.00781ω @ 0°C.	0.00627	624ω	1.2255	0.001,0045	1.774	
3	1657.1			130ω	1.0430	0.001,0250	1.772	1.775
4	1392.65			355ω std ω	0.8796	0.000,8648	1.7785	@ 22.2°C temp: of air
5	1108.15			1155ω Std ω	0.6974	0.000,6852	1.772	= 97.78 % cond: of pure soft copper offering a resistivity of 1598
6	232.25	copper rod 273.9 cms between distinct marks 0.2648 from dia 0.267 sq cms	equivalent length of 0.2564 sq cms ~~2707~~ 2680.0 ~~99.8~~ cmds	0.	1.			

Res: per cm. 5.70ω minutes @ 0°C. = 0.915ω per mile @ 0°C. = 1.003ω @ 22°C.

Resumé.

No. of Obs.	Mean resistivity	v	v²	Σv²	r.	Probable	Resistivity of pure copper @ 0°C	Standard at 22°C	Temp Coeff:	Ratio	% Cond:
5	1.775	4 1 3 2 3	16 1 9 4 9	39	0.74	1.775 ± 0.74	1598 Ω	1735.3	0.00388	0.9778	97.78 ± 0.08

By Matthiessen's standard this is 100% cond: of pure hard copper.

Breaking strain test

No. of Obs.	Pressure in cylinder	Area of piston sqin	Total pressure lbs.	Weight of piston lbs	Total Breaking stress	Area of wire	Breaking stress per sq in.	
1	31 lbs	77.056	2388	100	2488	0.044438	56,066	
2	31 "		2388	100	2488			

In three trials on the lathe, with one end of the wire free to move in the direction of the axis, the number of twists obtained before breaking was 22 twists in 12 inches.

Calibration of an alternating current ammeter intended for the purposes of electrocution.

This was an Edison ammeter from the New York Works, indicating up to 10 amperes. To make it more dead beat, a vane of mica about 1" square was set in a circular sector box of brass. The indications to alternating currents were found to be about half those of continuous currents. On this account the solenoid which consisted of two layers had to be exchanged for one of five layers. The calibration was effected by means of the Siemens alternating dynamo, and the Siemens dynamometer. With the latter the following readings were obtained on the 124 volt circuit:—

No. of Obs.	Watch	Amperes	Observed Deflection	Sq. root of Deflection	Constant	Mean	v	v^2	Result
1	1·63	8·504	88·5	9·42	0·9026		6.3×10^{-3}	39.69×10^{-6}	
2	1·81	9·444	106·5	10·32	0·9148	0·9089	5.9×10^{-3}	34.81×10^{-6}	0·9089 ±0·0024
3	1·90	9·912	118·8	10·90	0·9094		0.5×10^{-3}	0.25×10^{-6}	
					27·2265 / 9·0089			74·75 ×10⁻⁶	

The following observations were then made with the Siemens alternator making from 2025 to 2140 revs per min. (135 ~ to 142·7 ~ per sec)

No. of Obs.	Length of Det. Chord cm.	Dynamometer Reading	Sq. Root of Reading	0·0089 × Reg = effective current amperes	Lamps in circ.	Δ chord	Δ amp	Δ chord / Δ amp.	Positions Chord of integrations
1	8·95	73·0	8·66	7·87	19				
2	8·45	52·5	7·25	6·59	18	0·50	1·28	0·3907	7·5 8·80
3	8·175	45·0	6·71	6·099	17	0·275	0·49	0·561	7·0 8·87
4	6·85	27·0	5·20	4·727	15	0·325	1·372	0·369	6·5 8·40
5	5·80	20·3	4·50	4·090	13	1·05	0·637	1·648	6·0 8·075
6	5·15	16·6	4·075	3·704	12	0·65	0·386	1·684	5·5 7·495
7	4·25	13	3·606	3·278	11	0·90	0·426	2·113	5·0 6·80
8	3·60	10	3·163	2·875	10	0·65	0·403	1·613	4·5 6·09
9	2·60	6·2	2·49	2·263	9	1·0	0·612	1·633	4·0 5·38
10	2·0	4·5	2·12	1·927	8	0·6	0·336	1·786	3·5 4·73
11	8·9	69	8·307	7·551	18				3·0 3·80
12	8·25	47	6·856	6·231	16	0·75	1·320	0·568	2·5 2·19
13	7·85	40·75	6·384	5·803	14	0·4	0·428	0·934	2·0
14	6·45	23·25	4·822	4·383	12	1·4	1·420	0·986	1·5
15	5·2	17·2	4·148	3·771	10	1·25	0·612	2·043	1·0
16	3·6	10	3·163	2·875	8	1·6	0·896	1·786	0·5
17	2·75	6·8	2·609	2·371	6	0·85	0·504	1·687	
18									

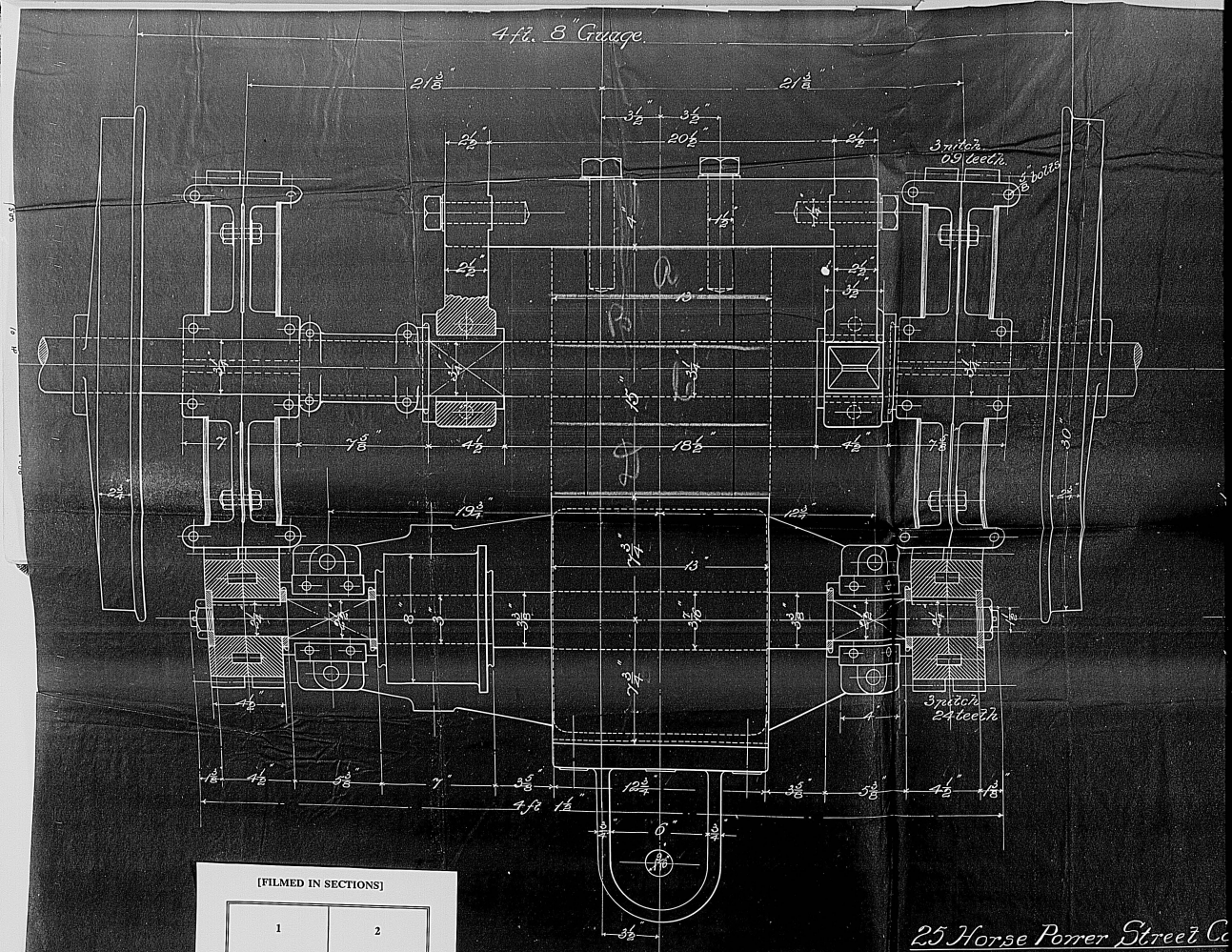
From these readings the chordal distances to the integers reckoned from the zero point are:— (radius 16·7 cm.)

	7·5	7·0	6·5	6·0	5·5	5·0	4·5	4·0	3·5	3·0	2·5	2·0	1·5	1·0	0·5
	8·84	8·44	8·140	8·05	7·72	7·075	6·6	5·68	4·74	3·8	3·0	2·2	1·65	1·1	0·55
Set at:	8·3	8·65	8·35	8·05	7·65	7·15	6·5	5·65	4·79	3·9	3·0	2·25	1·7	1·13	0·55

Resistance of the instrument 0·09 ω. Inductance at zero 0·65 h. at full load 1·07 h.

The impedance at full load and 130 ~ = 0·92 ohms.

With this scale inverted, the instrument indicated 3·3 amperes for 2 amp continuous c.
4·5 " " 3 " " "
5·8 " " 4 " " "

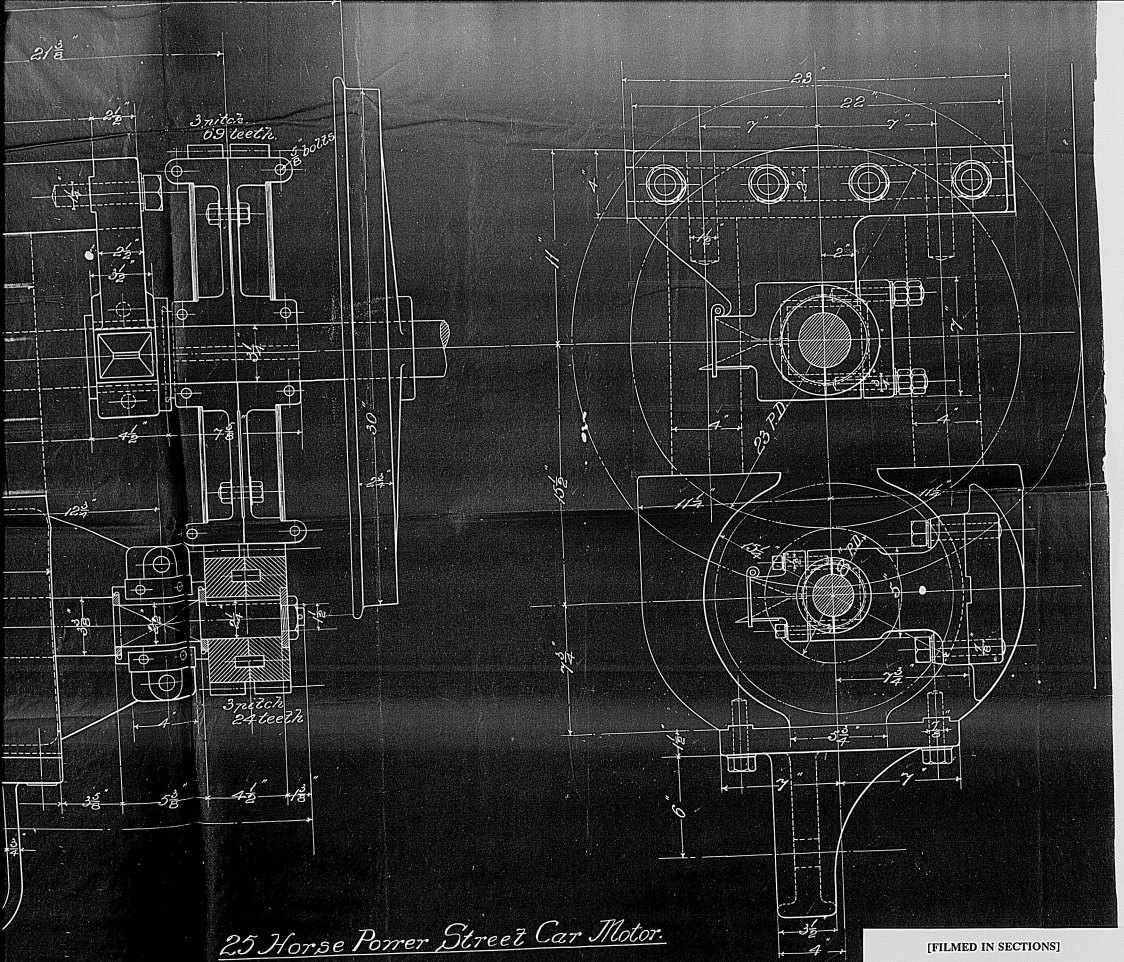


[FILMED IN SECTIONS]

1	2

25 Horse Porter Street Co

Dec. 12. 1890



25 Horse Power Street Car Motor.

Dec. 12. 1890.

[FILMED IN SECTIONS]

1	2

Calculations concerning a 25 HP. Street Car Motor whose blue print and description was received from the Engineering Department on the 18th December 1820.

This motor is of the Sprague general type, and gears directly to the car wheel axis with a velocity ratio of 28/8.
Speed of motor estimated for 800 r.p.m. corresponding to 24.1 mph.
Core of field-magnet 8½" wide by 4" thick. Presumably elliptical.
Assuming 30 sq. in. or 193.5 sq. cms. of cross-section at a saturation limit of 18,000 = 3,480,000 lines C.G.S. of which allowing 40% for leakage 2,090,000 will be useful.
The slowest speed will probably be 8 mph., not greater.
This represents 89.6 revs. p. m. of car wheel, or 311 r.p.m. of car motor = 5.2 revs. per second.

$$\therefore w = \frac{500 \times 10^8}{2.09 \times 5.2 \times 10^6} = \frac{50 \times 10^3}{10.87} = 4600.$$

The winding space on the armature is 0.4" deep and 44° peripherally. = 17.6 sq. in. The space per wire is thus 0.00383 sq. in = 0.0617" diam. covered. ~~Less~~ 6 layers would give 0.066" and 660 turns = 3960 turns in all. 7 layers would give 0.057" and 748 turns = 5236. The greater number must be selected. The diameter of bare wire would be 0.010" less than 0.057" = 0.046". = #17 B.&S. the nearest size 0.045". With 2048 c.mils.

900 c.mils per ampere are called for = 22.7 amperes. Double this current or 45 amperes will be the full load. That is 2270 Watts. The torque at unit radius with this current would be 2,090,000 × 4500 × 4.5 × 6.3 = 6.72 × 10⁸ dynes: = 6.80 × 10⁵ gms = $\frac{680}{453.6} \times 10^3$ gms = 1.499 × 10³ lbs = $\frac{15000}{10}$ at the pitch line, this is 1500 lbs., and at the axle $\frac{28}{36}$ of this or 115 lbs.

The surface of the field coils is about 3600 sq. cms. each. and it is proposed to expend 2500 watts in each at full load. This represents $\frac{25}{36}$ = 0.7 Watts per sq. cms.

See also p. 82

Classification of small sizes of motors as arranged with Mr Henderson 28th December 1820

Watts	HP equivalent
100	0.13
200	0.267
400	0.53
800	1.07
1400	1.78
2000	2.7

Classification suggested by Mr H. Ward Leonard in letter 27th Dec. 20.

187 Watts	1/4 HP	or in Watts	50
94	1/8 HP		100
375	1/2 HP		200
750	1 HP		1000
1875	2½ HP		2000
3750	5 HP		4000
5625	7½ HP		6000
7500	10 HP		8000

Calculation of the breadth of grooves in a Pacinotti tooth armature of ring type.

Let R = the external radius of the core (cms)
r = " internal " " " "
d = " depth of the core (cms) = $R - r$
n = " number of grooves
b = " breadth of each groove (cms)
s = " distance between the polar extremities measured along the core (cms)
φ = " total flux c.g.s
$\mathfrak{B}$ = " permissable density in the teeth
and $\frac{\varphi}{\mathfrak{B}}$ = α the active tooth surface

Then $2\pi(R^2-r^2) = 2\pi(2dr+d^2)$ is the total surface of core
Of this $2nbd$ = groove surface.
and $4sd$ = inter polar surface.

$$\therefore \frac{2\pi(2dr+d^2) - 4sd - 2nbd}{2} = \frac{\varphi}{\mathfrak{B}} = \alpha$$

$$\therefore \quad \alpha = d(\pi r + \pi d - 2s - nb)$$

$$\therefore \quad b = \frac{1}{n}\left\{\frac{\pi}{d}\, 2\pi r + \pi d - 2s - \frac{\alpha}{d}\right\}$$

$$= \frac{1}{n}\left\{\pi(2r+d) - 2s - \frac{\alpha}{d}\right\}$$

Calculations for a small motor of 800 Watts delivery at 110 volts terminal p. d.

Allowing 200 watts to be consumed in friction, the armature must transform 1000 Watts into mechanical effort. Allowing 20 volts drop in the armature at full load, the current will be 11.1 amperes, and the resistance between brushes (hot) = 1.8 ω. Of this allowing 15% for platinoid = 0.27ω, the remainder (1.53ω) is the resistance of the armature proper (hot). The resistance of one section, assuming 142 is 0.11460 (hot) = 0.1170 cool.

Allowing a total flux of 300,000 lines and a density of 15,000 = 20 sq: cms. total cross section or 10 on each side. With a square core, this is 3.163 cms. square = 1.25". With an external diameter of 7", this means an internal diameter of 4.5" (17.78 0 = 55.87 & 13.49 0 = 25.99)

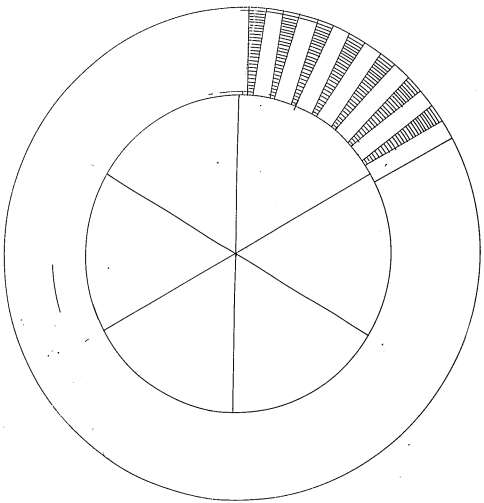
By the above formula, allowing an interpolar distance $s = 5$, and $\mathfrak{B} = 13{,}000$ we have $\alpha = 23.1$ $d = 3.16$

$$\therefore \quad b = \frac{1}{142}(3.14 \times 14.59 - 10 - 7.3)$$

$$= \frac{1}{142}(45.8 - 17.3) = \frac{1}{142}(28.5) = 0.678$$

The limiting breadth is found by $b = 25.99 - 142 \times 0.16 = 25.99 - 6.72 = 19.27/142 = 0.135$ = 0.27" say 0.25"; allowing 0.02 for insulation, leaves 0.235 winding space breadth.
The mean turn will be 8" = 0.667'.
The speed being 1700 revs: p.m. light = 28.3 p. second.
The number of wires needed all round will be $\frac{107 \times 10^6}{28.3 \times 3 \times 10^6}$

$$= \frac{107}{84.9} \times 10^3 = 1260 = 30 \text{ per groove.}$$



Thirty turns will make 20' having 0.117 ω, so that the wire must have 0.00585 ω per foot cool = #19 B.W.G. 0.0142". If this be covered to 0.050", there will be room for five turns per layer. Allowing 0.010" for body insulation, and 0.007" for space above, the depth of groove must be $6 \times 0.050 + 0.017 = 0.317$". The total breadth of core will thus be $1.25 + 0.634 = 1.884$"; $8.40' = 8.4 \times 5.34 \times 15 = 24.5$ lbs.

The total cross section of the armature being 20 sq. cms. the cross section of the core should be 20 sq. cms. = 6.18 cms diam. = 2.44" say 2.5".

Winding for 500 volts:- The winding space being 0.3" × 0.25" and 120 turns being needed per groove (10 × 12) the covered diameter of the wire = 0.025" and bare 0.018" # 26 B.W.G. 12 layers of 10 turns each.

Winding for 2500 volts:- the covered diameter must be 0.707 × 0.050 = 0.0353" = 0.028" bare = # 22 B.W.G. 56 turns. 8 layers of 7 turns each

The diameter of the mitis iron pattern core is 6.7 (2.67") 35.25 sq. cms.
The polar extensions 4.45 × 3.90. The Interflange 11.6
Weight of the pattern 922.5 gms.

The size of wire employed in the 500 volt winding is 0.018" cond. to 0.023". The resistance of one block is 0.780 for lower half and 0.980 for upper half @ 18°C. each 6 layer of 50 turns.

The weight of the armature body, grooved and ready for winding is 9 lbs 13½ oz. including spider which is 1 lb 11½ oz.
The weight of the field wire is 47 lbs. (wrought iron)
The weight of the motor with pulley when completed with 500 volt arm on the 24th January was 79 lbs.
The weight of wire on the 500 volt arm was 2 lbs 11 oz.
" " " " 120 " 3 lbs 5½ oz.
" " the 500 volt armature without shaft 12 lbs 8½ oz.
" " 120 " " " 13 lbs 2 oz.

The spool ~~with~~ mentioned on the opposite page was wound with 10 layers of 33 turns each or 330 turns in all of # 25 B.S. 0.017" wire ~~wound~~ Cotton covered (double) to 0.027".

Its resistance was 0.92Ω. Its ext: diam: 2.4.

The inductance was 3.14 h.

By calculation the diam: of wire should be

$4\pi \times 0.7854 \times 2.25 = 8.412$

$$d = -0.0127 + \sqrt{1.27^2 \times 10^{-4} + 0.00154\sqrt{\frac{8.412}{2.92}}}$$

$$+ 0.00154 \times 2.093$$

$$+ 0.003223$$

$$\frac{161}{0.003386}$$

$$+ 0.0582$$

$$= 0.0455 \text{ cm}$$

$$= 0.0179''$$

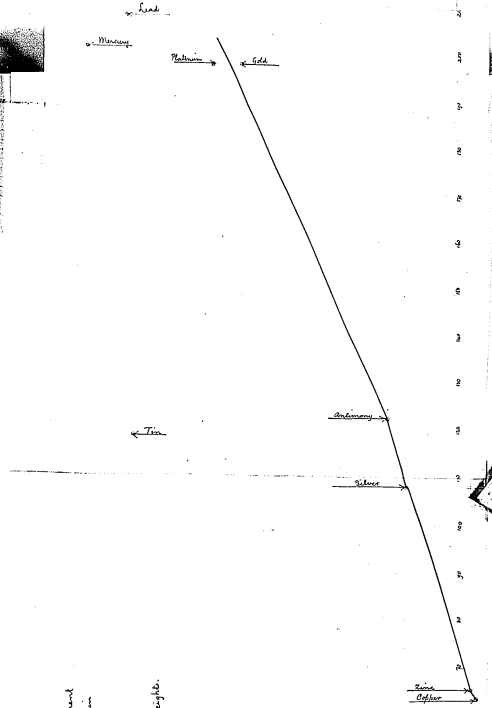


Chart of Thermo Electric Powers of different elements as deduced by Fleming Tomlin from Matthiessen experiments.

See end of the 9 are related in nearly linear order of their atomic weights.

Some facts in molecular physics arranged for Comparison.

The order of contact p.d. in air is taken as the standard.

	Metal	Atomic Weight	Sp. g.	Contact EMF in air	Thermo electric order 0°-100°	Electro chemical series	Resistivity	Volume expansion per °C	Heat Cond.	Melting point	Sp. heat
1	C.	12	3·5 (1)	0 (1)							
2	Na	23	0·97 (2)			1					
3	Mg	24	1·7 (3)			15					
4	Al.	27·4	2·7 (4)			14					
5	Mn	39·1	0·87 (1)			13	288g (1)				
6	Fe	56	8. (2)	0·495 (2)	−17·5 (11)	16					
	Ni	58·7	9. (10)			11	9638 (7)	4·0×10⁻⁶ (2)	0·1644	1200	0·106 (2)
	Cu	63·5	8·95 (2)	0·370 (2)	−0·1 (5) −3·3 (10)	10	12,358 (8)				
	Zn	65·2	6·86 (4)	1·096 (7)	−3·7 (9)	6	·15844 (2)	5·2×10⁻⁶ (4)	1·108	1090	0·090 (7)
	Ag	108·0	10·5 (12)		−8·0 (7)	12	5581 (5)		0·307	360	
	Sn	118·0	7·3 (2)	0·795 (2)	−0·1 (10)	5	1692 (1)	6·0×10⁻⁶ (1)		1000	0·056 (2)
	Pt	197·5	21. (14)	0·413 (2)	−0·9 (4)	8	13,103 (9)	6·2×10⁻⁶ (1)		2000	0·032 (3)
	Au	199	19·3 (17)		−1·2 (7)	3	8932 (4)	2·7×10⁻⁶ (1)			0·031 (2)
	Hg	200	13·57 (10)		0·416 (2)	2	26141 (3)	4·2×10⁻⁶ (3)		1200	
	Pb	207	11·3 (10)	0·858 (1)	0 (11)	4	9420 (6)	18×10⁻⁶ (1)			
	Bi	210	9·8 (10)		+97 (1)	9	19,468 (10)	8·4×10⁻⁶ (7)			0·03 (1)

One deduction from this table is that the thermo-electric powers are roughly in the order of atomic weights.

The heat conductivities are roughly in the ratio of the electric conductivities.

The specific heats are inversely as the atomic weights (D. & Pe. law).

Qn. the size of wire required to fill a magnet bobbin of the phonograph electromagnetic lift. Res. 1 to 2·5 Ω.

This interflange is 2·25, the int: diam. 1 cm. the ext: 2·5.

The area $(6.25-1)\times 0.7854 = 5.25\times 0.7854 = 4.125$

winding space $4.125\times 2.25 = 9.283$. $t = 0.005 = 5\times10^{-3}$ $t^2 = 25\times10^{-6}$

$$d = -\frac{t}{2} \pm \sqrt{\left\{t^2 + 0.00154\sqrt{\frac{9.283}{2.5}}\right\}}$$

$$\left\{25\times10^{-6} + 0.00154\times 6.9\right\}$$

$$\begin{array}{r} 0.00\cancel{2}96\cancel{7} \\ \underline{0.00\cancel{0}025} \\ 0.00\cancel{2}99\cancel{3} \end{array} \quad = 29.92\times10^{-6}$$

$$\pm\ 5.47\times10^{-2} = 0.0547$$

$$= 0.0547 - 0.005$$

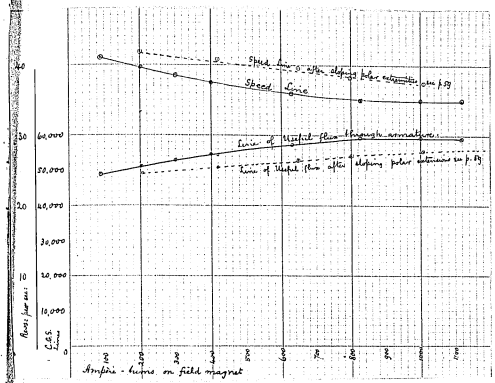
$$= 0.0500 \text{ cm.}$$

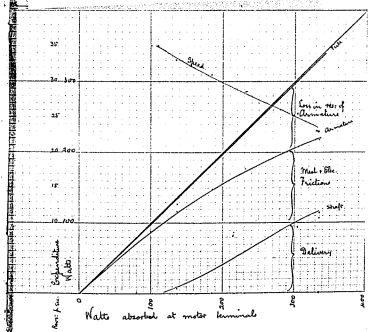
$$= 0.020'' = \#24 \text{ B.S. nearest BWG. \#25. silk cotton.}$$

Check $d = 0.0392\sqrt{\frac{9.283}{2.5}} = 0.0392\times 1.387 = 0.05444$ cm.

No. of Obs.	Lamps in Field circ.	Speed	Amperes in field circ.	M.M.F. in field.	Field: G. in air-gap circ.	Torque	Amperes	Volts p.d. on armature	Energy in armature	Drop in arm.
1	1	0.07	0.363	186.8	57°	1.540	1.14	120.75	137.7	17.1
2	2	0.169	0.876	257.7	54°	1.3760	1.018	"	122.9	15.3
3	3	0.245	1.270	373.5	53°.25	1.329	0.991	"	119.7	14.9
4	4	0.320	1.66	488.3	52.5	1.303	0.964	"	116.4	14.5
5	6	0.52	2.645	792.8	50.5	1.213	0.898	"	108.4	13.5
6	8	0.68	3.525	1037.	48.75	1.140	0.844	"	101.9	12.7
7	10	0.825	4.276	1258.	46.75	"	"	"	"	"
8	12	0.935	4.847	1426.	45.75	"	"	"	"	"

No. of Obs.	P.D. at motor terms	Speed	Current thro' motor armature	Energy in motor Watts	Drop in field	Amperes turns in field	Energy in field Watts	Drop in arm.	Energy lost in arm.	E.M.F. of arm.	Energy absorbed in effort	Scale Readings
1	120.0	0.220	1.146	137.5	5. Series	993	5.4	17.19	19.7	102.8	117.8	50 & 5.2
2	"	0.295	1.537	184.5	"	"	"	23.06	35.44	96.9	148.9	50 & 33.5
3		0.37	1.928	231.4	"	"	"	28.93	55.78	91.1	177.2	100 & 20 / 50 & 33
4		0.49	2.553	306.3	"	"	"	38.3	97.8	81.7	208.6	500 & 15 / 50 & 20
5		0.55	2.865	343.8	"	"	"	43.0	123.2	77.0	220.6	500 & 15
6		0.535	2.787	334.5	"	"	"	41.8	116.5	78.2	218.0	500 & 15 / 500 & 9
7		.										
7		0.260	1.355	162.6	0.4	317	0.54	20.3	27.5	99.7	134.5	50 & 20
8		0.540	2.813	337.6	0.8	658	2.25	42.2	118.7	77.0	216.6	500 & 15
9		0.160	0.834	100.1	0.3	195	0.25	12.5	10.4.2	107.2	89.4	0





Tests of the small $\frac{1}{8}$ H.P. (100 Watt) motor.

December 23rd & 24th 1890.

In the first test the field was separately excited. The current in the field was varied and measured, that in the armature correspondingly determined, and the speed also observed. The ratio of angular velocity of armature to indicator wheel (belt drive) was 114.2

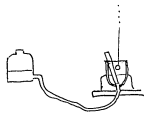
Number of turns = 5460 all round.

Gmms excited	Energy lost in rev. of armature	Energy consumed in effort.	Speed: of armature Revs. per min.	Speed: of armature Revs. per sec.	Magnetic flux through armature	Ampere turns.	Useful flux in drum coils for turns coil & circuit out of net	Energy per rev. per sec.	
103.6	119.6	118.1	2464	41.07	4.62×10^{6}	85	48,500	2.876	
105.5	15.5	107.4	2398	39.7	$4.866 \times$	205	51,100	2.704	
106.8	15.8	104.9	2318	38.6	5.022 "	297	52,730	2.719	
106.25	14.0	102.4	2244	37.4	5.203 "	389	54,640	2.738	
107.25	12.1	96.3	2158	36.0	5.456 "	631	57,300	2.675	
108.1	10.6	91.3	2102	35.0	5.653 "	825	59,370	2.608	
"	"	"	"	"	" "	1001	"	"	
"	"	"	"	"	" "	1134	"	"	

The motor was then planted in the tank and tested for efficiency, first with the field separately excited, and second with the field in series with the armature. Results as follow:—

Moment	Revs p.m.	Revs p. sec.	Moment × Revs. p. sec.	Watts delivered at motor pulley	Electrical Eff. of motor	Mech. Eff. of motor	Volts per revs per sec.	Energy absorbed by motor (watts)	Remarks
410	1988	33.1	1357×10^{4}	8.379	0.857	0.061	3.106	109.4	Driving library model, 250w full s.c. armature light. Load 2 in series. 110v 2.3 amp
1675	1860	31.0	5192 .	32.0	0.807	0.173	3.13	116.9	
3400	1718	28.6	9724 .	60.0	0.766	0.259	3.21	117.2	- 1 lamp.
6050	1520	25.3	1.531×10^{5}	94.4	0.681	0.308	3.23	114.2	- 100w
7500	1378	23.0	1725 .	106.4	0.642	0.309	3.35	114.2	- 100w + 1 lamp in multiple
7950	1406	23.4	1860 .	114.7	0.652	0.343	3.34	103.3	- 4 lamps.
1000	2100	35.0	3.5×10^{4} .	21.6	0.827	0.133	-	102.9	
7500	1407	23.4	1.755×10^{5}	108.2	0.642	0.321	-	108.4	- 4 lamps
0	-	.	-	-	0.89	-		104.2	

When the motor armature was driven light in the unexcited field by the 250 Watts library model, the speed was 1750 revs, and the moment 900 cm-gm. The energy was therefore 16 Watts. This is the mechanical friction at 1750 revs.

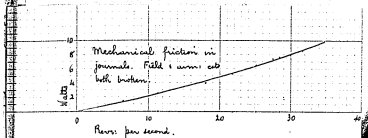


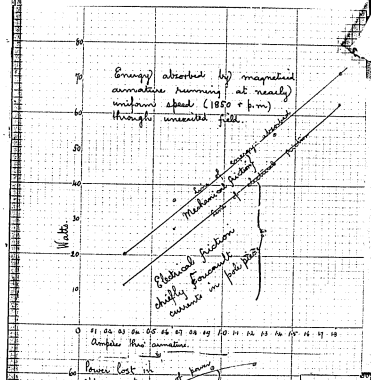
Description of an experiment made 25th Dec. 90, to observe the attraction of solids in water.

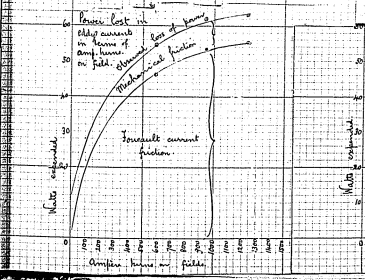
A vertical glass tube about 3.5 cms in diameter, and 1040 cm long descends from the Ore Milling room on the top floor to a stone room in the cellar. Beneath the opening, a glass jar with a stopcock was solidly set. A bottle filled with water was connected to this with a rubber pipe in such a manner that by raising or lowering the bottle, the receptacle could be filled with water or emptied. A sphere of tin 2.5 in diam. was suspended in the receptacle by a German silver ~~cotton~~ 0.01 in diam. single silk cement to 0.020". This wire was fastened at the top of the long tube. A large piece of tin was set in the receptacle so as to almost touch the freely suspended sphere while motionless. The distance between the plate and sphere being about 0.01 and the diameter of the glass receptacle itself being about 15 cms. All being prepared, the water was allowed to slowly enter the vessel, and the results watched for. These were:— 1st The moment the water touched the bottom of the sphere, the latter moved away from the plate. As the level rose, the sphere approached the plate, and finally when covered with water, it rested against the plate enclosing air at the point of contact. On dislodging the air, it was apparent that instead of any attraction between plate and sphere, there was if anything a greater distance between them in water than in air, Several unsuccessful attempts were made to use finer threads of silk or wire to support the sphere, and finally the fall of the sphere broke the glass receptacle.

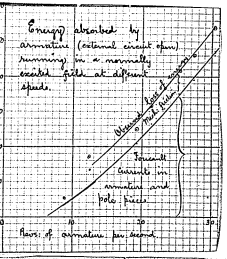
On the friction of a sprocket-chain upon a rubber-covered pulley 30th Dec. 90

The Street-car motor was armed with a 4½ sprocket wheel. The sprocket chain ran over ~~the~~ the 24" wheel faced with rubber, and the tractive power observed by Prony brake resting on the scales. The chain was tightened by an 'idler'. The chain slipped on the rubber when 37.5 lbs was indicated at 8 feet radius = 300 lbs: at 1' rad: 24 such chains would slip at 7200 lbs: pull on the chain. The 24" pulley was making 48 revs: per min (equivalent to 4.3 m.p.h. of car) and the energy absorbed by the motor was about 6 amp @ 350v. = 2100 Watts.


Mechanical friction in journals. Field & armt. cd. with broken.
Watts.
Revs. per second.


Energy absorbed by magnetised armature running at nearly uniform speed (1850 r.p.m.) through unexcited field.
Loss of energy in hysteresis
Mechanical friction
Electrical friction chiefly Foucault currents in pole pieces
Watts.
Amperes thro' armature.


Power lost in eddy currents in terms of amp. turns on field.
Normal loss of power
Mechanical friction
Foucault current friction.
Watts expended.
Ampere turns on field.


Energy absorbed by armature (external circuit open) running in a normally excited field at different speeds.
Normal loss of power & mech. friction
Foucault currents in armature and pole pieces
Watts expended.
Revs. of armature per second.

Analysis of friction losses in the 100-Watt Model whose heat is recorded on page 46.

The motor was fitted with two collector-rings over its commutator, and brushes resting on them in such a manner that a current could be supplied to the rotating armature at opposite fixed points in the ring. The machine was then floated, and the following measurements made.

1st Test. Pure mechanical friction, armature + field circuits open

No. of Obs.	Revs. of Counter p.m.	Revs. of arm. p.m.	Revs. of arm. p. sec.	Scale Reading	Moment cm. gms.	Moment × Revs. p. sec.	Watts expended in friction	Watts per rev.	
1	28	397.6	6.63	5.0 @ 7.2	360	2.387×10^3	1.47	0.222	
2	48	681.6	11.36	" 7.2	360	4.090	2.52	"	
3	76	1079	18.0	" 7.2	360	6.48	4.0	"	
4	92	1306	21.8	" 7.7	385	8.39	5.17	0.237	
5	106	1505	25.1	" 8.3	415	10.42	6.42	0.256	
6	116	1647	27.5	" 8.7	435	12.96	7.37	0.268	
7	120	1704	28.4	" 8.7	435	12.35	7.62	"	
8	126	1789	29.8	" 8.7	435	12.96	7.99	"	
9	134	1903	31.7	" 9.2	460	13.79	8.50	0.27	

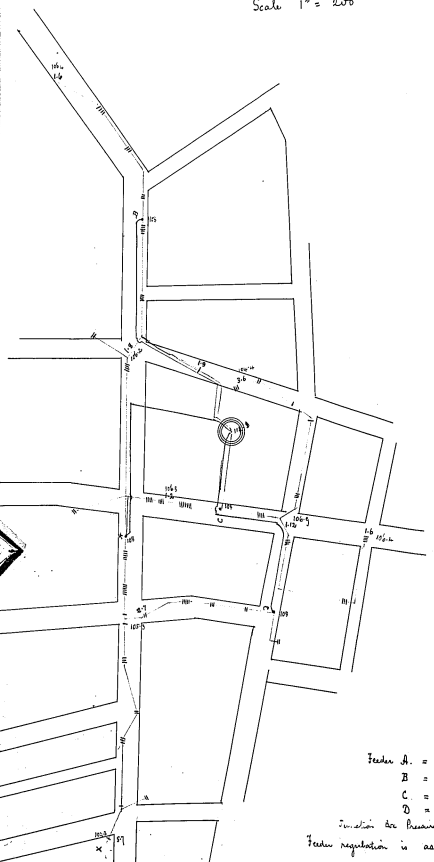
2nd Test. Mechanical friction + effect of a magnetised armature.

No. of Obs.	Revs. of counter p.m.	Revs. of arm. p.m.	Revs. of arm. p. sec.	Scale - Reading.	Moment. cm. gms.	Moment × Revs. p. sec.	Watts of power absorb.	Current in arm.	Better or worse than friction
1	122	1974	31.23	{100 @ 5. / 50 @ 10.9}	1045	3264×10	20.13	0.313	12.6
2	130	1846	30.75	{100 @ 15 / 50 @ 7.8}	1890	5.812	35.83	0.651	27.5
3	128	1817	30.3	{100 @ 20 / 100 @ 10 / 50 @ 7.15}	2910	8.818	54.36	1.354	46.2
4	128	1817	30.3	{100 @ 20 / 100 @ 12 / 50 @ 7.}	3850	11.670	71.94	1.823	63.7

3rd Test. Mechanical friction + effect of magnetised fields, armature at broken

No. of Obs.	Revs. of Counter p.m.	Revs. of arm. p. min.	Revs. of arm. p. sec.	Lamps on circ.	Ohmic	Current in field	Amplitude of swing in field	Scale	Readings	Moment	Watts absorbed	Better than magnetic friction
1	20	284	4.4	1	0.090	0.469	110	50	@ 12.5	625	1.7	0.9
2	40	568	8.8	6	0.480	2.50	585	50	@ 27.9	1395	5.4	3.6
3	62	881	14.7	"	"	"		{100 / 50}	@ {10 / 17.8}	1890	17.1	13.7
4	78	1108	18.5	"	"	"		{100 / 50}	@ {15 / 13}	2150	25.1	20.7
5	90	1278	21.3	"	"	"		{100 / 50}	@ {20 / 10.9}	2395	31.5	26.3
6	98	1392	23.2	"	"	"		{100 / 50}	@ {20 / 11.3}	2560	36.6	30.7
7	108	1534	25.6	"	"	"		{100 / 50}	@ {20 / 12.1}	2640	41.6	35.1
8	116	1647	27.5	"	"	"		{100 / 50}	@ {20 / 12.5}	2710	46.0	38.9
9	128	1818	30.3	"	"	"		{100 / 50}	@ {20 / 18}	3900	54.2	46.0
10	120	1846	30.8	10	0.7950	4.044	945	{100 / 50}	@ {20 / 23.3}	3265	62.0	53.7
11	128	1818	30.3	"	1.015	5.29	1238	{100 / 50}	@ {20 / 28.2}	3410	63.7	55.5

Part of Trenton N.S. Copied from Directory Map
Scale 1" = 200'



Feeder A. = 700' 6.3
B = 770' 6.95
C = 220' 2
D = 670' 6.27
Insulation for Pressure = 10K
Feeder regulation is assumed.

Calculation of Drop in conductors of the Trenton Plant operated on 3-wire (or approximately) 3-wire system 1886

There were 1800 lamps operated in 106 different positions on the chart, or about 17.1 lamps at each position on the average. The lamps in 1886 were of 105 volts, and 4.25 N. per candle and if all were of 16 cp = 68 Watts = 0.648 amp each, and 17 lamps = 11.0 amperes to each point.

The mains are assumed to have been # 1 B.&S. gauge 83,694 c.mils having a resistance of 1.233×10^{-4} ω per foot.

The feeders were assumed to have been #00 B.&S. gauge, 133,079 c.mils having a resistance of 7.757×10^{-5} ω per foot, but the feeders were all quadruplex, so that their equivalent resistance would be 1.939×10^{-5} ω per ft with a cir. mileage of 582.316 equivalent.

There are four principal sections in this system as follows:—

1st A to D
5 @ 50'
6 @ 150
1 @ 220
13 @ 230
2 @ 300
5 @ 430
3 @ 510
2 @ 600
D - 680
106 = 37

2nd A to B
2 @ 120
6 @ 300
7 @ 370
4 @ 790
5 @ 900
B 930
Sep. off B 10
28

3rd A to C
8 @ 200
7 @ 300
C 400
15

4th C to D
4 @ 120
10 @ 180
3 @ 250
7 @ 330
3 @ 360
Sep. off D 2
26

The C.G. of these feeders are 2,850 / 2,890' / 5,310 / 5,320' / — / 2,440 / 2,260'
and of the subcircuits are 25 @ 220 from A; 12 @ 460 = 220 - D; 8 @ 330 from A; 10 @ 740 = 370 from B; 8 @ 200 from A; 7 @ 100 - C; 14 @ 165 from C; 10 @ 340 = 120 - D

The circuit AIX		D offset	Offset AB	Offset CD
	1 @ 15	3 @ 200	3 @ 370	3 @ 20
	3 @ 120	4 @ 400	3 @ 220	1 @ 300
	2 @ 250		4 @ 360	1 @ 380
	3 @ 370			2 @ 500
	1 @ 580			3 @ 570
	3 @ 610			
C.G. are	13 @ 340	7 @ 310	10 @ 220	10 @ 360

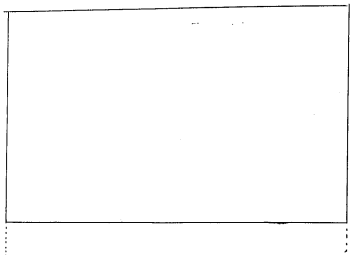
Off Feeder A	B Offset	C	D
25 on AD @ 220	10 @	7 on AC @ 300	12 on AD @ 220
8 " AB @ 330	10 on BA @ 170	14 - CD @ 165	10 - D @ 120
8 - AC @ 200			2 - Offset @ 100
106 = 41	20	21	24

The drop on A = $20.5 \times 700 \times 11 \times 1.939 \times 10^{-5}$ = $2.05 \times 7.0 \times 1.1 \times 1.939 \times 10^{-1}$ = 3.06 volts
B = $10 \times 770 \times 11 \times 1.939 \times 10^{-5}$ = $1 \times 7.7 \times 1.1 \times 1.939 \times 10^{-1}$ = 1.64
C = $10.5 \times 220 \times 11 \times 1.939 \times 10^{-5}$ = $1.05 \times 2.2 \times 1.1 \times 1.939 \times 10^{-1}$ = 0.493
D = $12 \times 670 \times 11 \times 1.939 \times 10^{-5}$ = $1.2 \times 6.7 \times 1.1 \times 1.939 \times 10^{-1}$ = 1.72 } Off

The drop on AD = ~~1.05 × 220~~ $4.000 \times 1.233 \times 10^{-4} \times 5.5$ = $4 \times 5.5 \times 1.233 \times 10^{-1}$ = 2.71 — 2.7
AD X = $13 \times 3.40 \times 5.5 \times 1.233 \times 10^{-4}$ = $1.3 \times 3.4 \times 5.5 \times 1.233 \times 10^{-1}$ = 3.0. Total 5.7 — 5.7
AB = $2600 \times 1.233 \times 10^{-4} \times 5.5$ = $2.6 \times 1.233 \times 5.5 \times 10^{-4}$ 1.76 — 1.9
B offset = $2310 \times 1.233 \times 10^{-4} \times 5.5$ = $2.31 \times 1.233 \times 5.5 \times 10^{-4}$ = 1.56 — 1.6
Station offset = $200 \times 1.233 \times 10^{-4} \times 5.5$ = $2.0 \times 1.233 \times 5.5 \times 10^{-4}$ = 0.14 — 1.9
AC = $1800 \times 1.233 \times 10^{-4} \times 5.5$ = $1.8 \times 1.233 \times 5.5 \times 10^{-1}$ = 1.22 — 1.2 } 2.4
CD = $1650 \times 1.233 \times 10^{-4} \times 5.5$ = $1.65 \times 1.233 \times 5.5 \times 10^{-1}$ = 1.12 — 1.1
C Offset = $3660 \times 1.233 \times 10^{-4} \times 5.5$ = $3.66 \times 1.233 \times 5.5 \times 10^{-1}$ = 2.48 — 3.6
D Offset = $2200 \times 1.233 \times 10^{-4} \times 5.5$ = $2.2 \times 1.233 \times 5.5 \times 10^{-1}$ = 1.49 — 1.6

The drop on the mains varies from 1.1 to 5.7 · Mean drop on 9 longest points 2.16
" " " feeders " 3.6 to 2.5 Mean drop - 4 feeders 2.73.

Plan and Side Elevation of boat. (Internal dimensions)
Scale 1" = 1 foot.



As actually constructed, the outer tank is 167 × 106 × 36.5 internally
The inner tank is 153.5 × 91 × 26.4 externally } Weight 1150 lb = 68.5 kg.
148.5 × 86.5 × 22.4 internally }
14000 sq. cms. of outer base.

On the dimensions of a tank to float 400 lb motors. (50)

400 lbs = 181,440 gms = 181,440 c.c. of water say 200,000. With an immersion of 15" cms. this gives an area of 13,330 sq. cms. With a breadth of 3' (91.5) = 145.7 cms. = 57.4 = 4'. 9½". Say 3' × 5' × 6' immersion + 9" free board. 10" ext. depth.

Calculation of the length and size of wire needed on the magnets of the small Edison 100-Watt motor.

The diameter of the core is 1.25", and the length between flanges 3.6". The mean diam. may be taken as 1.75", and the mean circum. = 0.458'. If the current needed to drive the motor light, be taken as 0.50 amp., and 300 amp turns be adopted for the light magnetization, see the curve on p. 46., then 600 turns will be needed, and the length of wire = 300' approx. The maximum current will be 2.5 amperes, and the fall of potential should not exceed 2.5 volts = 1 w., then 1 w of # 18 B.W.G. should be used = 1.7 lbs. say 1 lb. 12 oz. 233' = 500 turns. s.c. wire 0.0449" to 0.0457" so that there will be 60 turns per layer and 8 layers or 0.48" deep.

Data of Edison Gravity Voltmeter

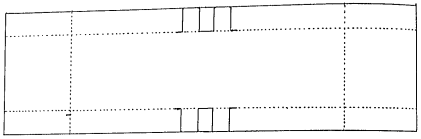
This instrument is described in Record Book (smaller) # 3 p 69 + 81. It consists of a balance scale beam having a solenoid on one arm that is attracted by a similar larger fixed, and coaxial solenoid on the base. The two solenoids are in series. Before the instrument was sent to the Paris Exhibition, the range was 5 volts and 0.28 gms on each side for a current of 0.75 ampere. On its return to the Laboratory from the Minneapolis Exhibition the main knife edge was found broken and after repair and shortening, the range was greater and the instrument not so sensitive. The fixed solenoid was then changed. It consisted of 396 turns (6 layers of 66 turns each) of # 18 B.W.G. wire 0.0449" silk covered to 0.0457". The brass shell had an ext. diam. of ~~1.8~~, weighed empty 117 gms, and had an interflange of 10.3. This winding was changed for four layers of 225 turns (900 in all) of platinoid wire 0.011" covered to 0.0175". This winding was found to have too much resistance ~~and~~ (1200 ω) and was again changed for 772 turns & layer of 96.5 turns of 0.020" wire s.c.c. to 0.0236". Ext. diam. 5.9 Res. 5.25 = 0.14 c.

The inner solenoid consists of 4 layers of 65 turns (260 turns in all) of 0.0449" d. silk c. to 0.0558". The diameter over wire is 3.06, the internal diameter of the shell 1.82, and the winding diameter (external of shell) 2.05. Length of solenoid shell 10.5, interflange 9.75. Weight of solenoid, shell (rubber) and earring 260 gms.

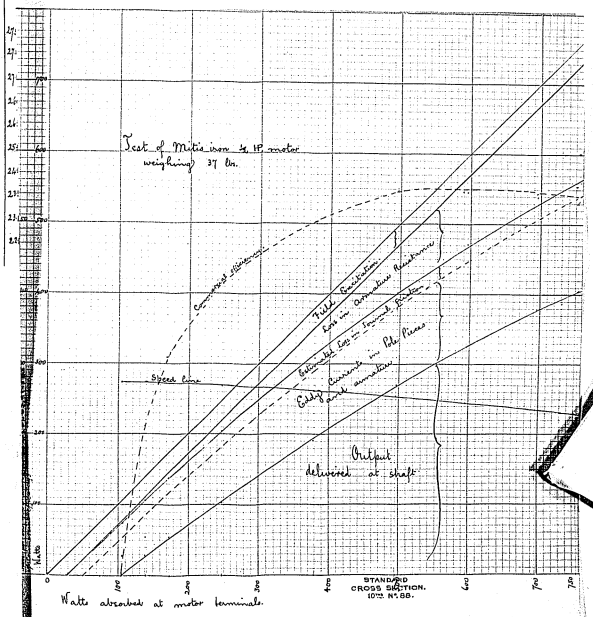
With the last winding, the pull was 0.225 gms with a current of $\frac{103}{200}$ = 0.1136 ampere, ~~and~~ or 220.5 dynes, but the sensitiveness to variation of current was not sufficient.

A new knife edge was then made for the instrument to increase the distance between the center of inertia, and the point of suspension. When this altered, a current of $\frac{103}{140}$ = 0.779 ampere exerts a pull of 0.63 gm and a variation of pressure from $\frac{106}{140}$ to 112 was nearly sufficient to carry the instrument over the whole scale.

Res. of interior solenoid and connecting wire 0.55 ω
Instrument sent to Mr Edgar, Boston, for trial 16th Jan-91.



No. of Obs.	P.D. at motor terminals	Current through motor	Current through armature	Energy in Watts	Energy in field coils	Energy in armature	Calculated drop in armature	Em.f. generated by armature	Energy lost in armature	Energy exerted in mech. effect	Revs. of armature p.m.	Field energy
1	121	0.233	–	28.2	28.2	–	–					
2	"	0.860	0.627	104.1	"	75.9	0.28	118.2	34.8	74.1	1650	27
3	"	1.146	0.913	138.7	"	110.5	0.40	117.0	39.9	106.8	1645	27
4	"	1.433	1.200	173.4	"	145.2	0.53	115.7	6.3	138.9	1625	27
5	"	2.032	1.799	246.	"	217.8	0.79	113.1	14.3	203.5	1615	26
6	"	3.126	2.893	378.3	"	350.1	1.27	109.3	36.8	313.3	1575	26
7	"	4.090	3.857	494.9	"	466.7	1.70	104.0	65.6	401.1	1530	25
8	"	4.923	4.690	595.7	"	567.5	2.06	100.4	96.6	470.9	1470	24
9	"	5.756	5.523	696.5	"	669.3	2.43	97.7	128.8	534.5	1410	23
10	"	6.242	5.809	731.2	"	702.9	2.7.9	92.1	162.1	540.8	1380	23
11	"	6.251	6.018	756.4	"	728.2	28.9	92.1	174.0	554.2	1370	23
				4343.4		4333.1						



Test of Mitis Iron 3/4 H.P. Motor 27th Dec. 90.

This motor has an armature whose data are given on page 147 Book III. The field magnet and pole pieces are of mitis iron. The weight of the machine on a wooden base 11" × 11" is 37 lbs, and its actual extreme dimensions are 9" × 10" × 11". The armature has 42 grooves each 0.21" wide and 0.325" deep holding 50 turns 10 layers of 5 turns each of #23 B.W.G. 0.025" s.c.c. The cross section of iron in the ring is 6.75 sq cm (25 × 27) The diameter of the commutator is 1.43" (42 segments mica insulation). The brushes are blocks of copper gauze, resting nearly vertical, and cover nearly 3 bars. The core has a diameter of 1.875" and the interpolar length is 3.8". The diameter over wire is 2.875". The resistance of the armature coil (including platinoid) is 4.4 ω, hot 4.8 ω. The inductance of the armature with 2 or 3 amps of current is 0.100 H (100 mh). The resistance of the field coil is 520 ω, the inductance 42.6 H.

The motor was floated, and coupled to the 1000 Watt Edison dynamo

Field R.M. amps.	S.M.F. (Volts)	Scale Gauge	Reading Dist.	Moment	Moment×4/3	Input Watts	Output-Stationary Friction Watts	Mechanical Efficiency	Armature Electrical Efficiency	Magnetic Data	
		–	–					–			Field only (1)
		–	–				74.1	–	0.976	$\phi = 2.2 \times 10^5$	Running light (2)
		50 @ 4.8 100 @ 15		1740	1.073×10^7	29.4	77.4	0.212	0.967	$\phi = 1.1 \times 10^5$	Driving armature light (3)
		50 @ 4.5 100 @ 10 100 @ 20		3225	1.988	53.9	85.0	0.241	0.957	$\phi = 1.6200$	Driving armature and the sp. exc. field (4)
2.1		50 @ 23 500 @ 10		6150	3.792	102.0	101.5	0.4134	0.934	in the first column by paper and tin	
2.12		50 @ 23 100 @ 10 100 @ 23		11,750	7.244	190.6	122.7	0.3844	0.895		1 lamp (5)
2.05		50 @ 25 100 @ 10 50 @ 16 100 @ 23		17,200	10.60	270.3	130.8	0.5446	0.859		3 " " (6)
2.10		50 @ 25 50 @ 5.5 50 @ 25 100 @ 10		21,550	13.29	325.6	144.9	0.5546	0.830		5 " (7)
2.16		50 @ 25 100 @ 5.5 50 @ 25 100 @ 10		26,100	16.09	378.2	161.3	0.5443	0.807		7 " (8)
2.05		50 @ 25 100 @ 5.5 50 @ 25 100 @ 10		27,250	16.80	386.4	154.4	0.529	0.769		9 " (9)
		50 @ 25 100 @ 5.5 50 @ 25 100 @ 15		28,800	17.76	405.0	144.2	0.535	0.761		11 " (10)
											12 " (11)

Further considerations and Data connected with the proposed Street-Car motor improved Sprague type represented on page 36.

In The data received from the Engineering Dept. on the 18th Dec were as follow:- Armature Drum. 14" core diam: face 12.5"
Commutator 72 divs.
Estimated speed 800 r.p.m. (necessary to reduce to 300)
Armature winding 900 c.mils per amp.
Field bore 15½":
Clearance over all ⅛".
Field core 4" × 8½" wide × 15" long.

The data received on the 31st Dec. were :-
Armature Drum 14" core diam: face 13".
Area of field core 51 sq: in:
Length - - - 15"
Area of polar surface 460 sq: in.
Speed 300 to 800 r.p.m.

With the new data, allowing 54 sq: in: of cross section in the field core = 329 sq. cmd. With 18,000 lines per sq. cm. this represents 5922,000 lines. Allowing 33% leakage gives 3,968,000 lines usefully employed, say 4×10^6 as an extreme limit.
To develop 500 volts the no: of wires all round must be
$5.0 \times 10^{10} / 4 \times 10^6 \times 5 = 5.0/2.0 \times 10^3 = 2,500$ or 1250 drum turns.
The field bore being 15½" the winding external diam: is 15".
The core being 14", allowing for insulation and binding, the winding depth is 0.4". The mean diam = 14.4" or circum: of 45.24" and a winding area of 18.1 sq in:
This space occupied by 2500 ~~turns~~ wires will give 18.1/2500 = ~~18,000~~ 7240 sq: in: per turn. = 0.085" diam: = 0.09" bare wire = 5,625 c.mils and allowing 900 c.mil. per amp: = 6.00 amperes
The output of the machine at 100% efficiency would therefore be 12 × 500 = 6 kilowatts.

The #6 Edison standard dynamo, has a core 8.25" in diam. = 53.45 sq: in. It generates 125 volts @ 1500 revs. with 192 wires on its armature (96 turns). The diam: of wire is 0.180 bare or 32,400 c.mils. and this wire carries $\frac{6 \times 20}{2}$ = 60 amperes, or an area of 540 c.mil. per ampere.
If it generated 500 volts at the same speed, and with the same winding space, the covered diameter would be 0.095 ÷ 2 say 0.0975 or a bare diameter of 0.088". If then it had to generate 500 volts at 300 revolutions, the diameter of covered wire would be reduced √5 or 2.23 times 0.044" covered = 0.034" bare = 1156 c.mils = 2.14 amp. The machine will now generate 4.28 × 500 = 2140 Watts while its original power was 15000 Watts.

Resumé

Quadripolar Gramme Ring Dynamo

4000 Watts

80 volts 50 amperes

500 revs: per min.

Limiting temp: elevation 50°F.

Armature Thin sheet iron.

External diam: over binding: 23.190

" " over wire 23.125

" " over body wire: 22.925

" " over core 22.825"

Internal " under core 18.55"

" " wire 18.35" or 18.20

Breadth over core 6.75

over wire. 7.0 or 7.2

Cross section of core 14.90 sq. in. = 93 sq. cm.

Commutator divs: 240

Winding 720 turns of # 12 B+S.

Diam: of bare wire 0.081"

" cond: wire 0.095"

Circular mils 6561

Res: mils per amp: at full load 486

Length of armature wire 1150'

Weight " " " 23 lbs.

Field: Cast Mitis iron. Bore 23.34

Diam: of cores: 4.5"

Cross section of cores. 15.9 sq. in.

Area of polar surface. 71.5 sq. in.

Entefer. 0.268"

Winding: #19 B+S.

Diam: of bare wire 0.036"

" " cond: wire. 0.0444" S.C.C.

Length wire on each core 13,360'

Weight " " " " 152.4 lbs. 200 in all

Resistance " " " " 107 ω.

External diameter of wound core over wire 8.3"

over surf. 8.5"

Current in field at full load. 3 amp.

Power " " " 240 Watts.

Fall of pot. in arm: 7 volts.

Energy expended " 371 watts

Electrical loss of energy in field + arm: 611 Watts.

independent of eddy current.

Revised Calculations for a 4 Kilowatt Machine to be constructed by the Engineering Department

See p. 20.

The breadth of the armature is 17, the depth 5.5, the cross section 93.5 cm. Allowing only 0.8 of this for available for iron gives 74.8 sq cm.: With a density in iron of 10,000 this gives a useful flux of 750,000, and the polar flux = 1.5×10^6. The e.m.f. to be developed is 90×10^8 = 9.0×10^8 and the revs. p.s. are 8⅓ = 8.33. Hence the no: of wires all round will be $9.0 \times 10^8 / 8333 \times 1.5 \times 10^7$ or 720. Say 800. The diam: of the armature internally is 18.25" corresponding to a circ: of 57.3" and the breadth per wire is 0.0716", allowing 0.014", this becomes 0.058" # 17 BWG 3364 c. mils = 250 c. mils. per amp. The length of one turn on the armature is 19" = 1.6'. The total length of wire on the armature will be 1280' and the res: = $1.280 \times 3.069 \times 1/16 = 0.244$ cool or 0.3 ω hot. This means a drop of 15 volts at full load.

If 720 wires be taken the breadth for each wire is 0.0796". Allowing 0.014" = 0.065" = # 16 B.W.G. the resistance in this case would be $720 \times 1.6 \times 2.444 \times 1/16 \times 10^{-3} = 0.177$" = 0.2 ω hot and a drop of 10 volts at full load. The c.m. = $\frac{42.25}{13.45}$ = 313.

If now the ext: diam: only be considered 22.9" = 71.94" circ: of which 10% may be considered unavailable, leaving 64.75". There with 760 wire, the breadth per wire = 0.085", and allowing 0.013" for insulation gives 0.072" # 15 BWG. 5184 c. mils = 384 c. mils per amp. res: per foot = $2 \times 10^{-3} \times 760 \times \frac{1.6}{16}$ = 0.152 ω cool or 0.17 ω hot, and the drop at full load = 9 volts.

With 720 wire, the diam: of the bare wire = 0.09 and allowing for insulation 0.014" = 0.081" # 18 B.S. = 68.4 c. mils, equivalent of 22.9 + 0.1 = 23 × 3.14 = 72.25" = 6561 c. mils, or 486 c. mils per amp. The res: = $6.58 \times 720 \times \frac{1.6}{16} \times 10^{-3}$ = 0.1184 ω cool = 0.13 ω hot = 7 volts drop at full load.

The useful flux being 1.5×10^{6} × 1.6 for r = 2.44×10^4, and 4" cross gives 81 sq. cm. $B = 2.44 \times 10^4 / 2 \times 81 = 1.5 \times 10^6$

Allowing 4.5" = 15.9 × 6.45 = 102.6 and a density of 12,000 The mean turn on the core will be 1.5' approx.

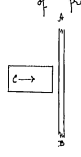
The polar surface is 26 × 17 = 442 sq. cm. and the entefer = 0.1 + 0.125 + 0.1 = 0.325" = 0.82 cm. The reluctance then to each core circuit in air = 0.64/321 = 0.00244 lucts. The reluctance of the armature is 33 × 0.0015/75 = 0.0006. The reluctance of the core is 56 × 0.002/60 = 0.002. Total reluctance 0.01 in each core circuit. The flux needed being 750,000 the M.M.F. called for is 7,500, and the amp: turns = 6000, allowing for armature effect, say 7000 ampturns. The surface of each coil is 800 sq. cm. and allowing 25 sq. cm. per watt = 60 Watts. = 0.75 amp: = 9,300 turns. The resistance hot of the coil must be 107 ω. and 9300 turns = 14,000' = 131' per ω = # 19 B.W.G. = 0.19 lbs. per ω. = 24.8 lbs. per core 0.036" covered to 0.0444" = The space occupied will be 29 c. in. = 36.4 sq. in. = 4.6 to 8.3". The length will be 13,360' and the mean diam: 6.45" = 20.3" circ. = 1.7' = 7,850 turns. 180 turns per layer, and 44 layers. = 1.9" deep.

If wound for 20 volts on each core, the current = 3 amperes and the resistance 6.67 ω hot = 6 ω cold. the number of turns needed = 2300 and the length 3910' = 652' per ω = # 12 B.W.G. 0.072" cond: 6 0.050" 47.2 lbs. on each core. 500' per ω = 3000'

Also to determine under these conditions the space through which the impact drives the compresses the body.

We have
$$v = V\cos(t\sqrt{\mu})$$
$$ds = V\cos(t\sqrt{\mu})\,dt$$
$$\therefore\ s = V\frac{\sin(t\sqrt{\mu})}{\sqrt{\mu}}$$
when $t = \tau$ the space is a maximum
$$s = \frac{V}{\sqrt{\mu}}$$
$$= V l\sqrt{\frac{\rho}{\eta}} \quad \text{or} \quad V\sqrt{\frac{m l}{\eta a}}$$
For the steel cube of unit edge length considered
$$s = 2V \times 10^{-6}$$

On the Mathematical Laws connecting the period of free impact in simple masses, with their elastic moduli



Let AB be a perfectly rigid and unyielding barrier.
" C . . body in the form of a rectangular parallelepiped, moving with a velocity V in free space.
" m be the mass of C
" a be the area of the impinging face
" l - - length . . body
" s - - distance moved over by the body dating from the ~~the~~ instant of impact
" t " the time dating from the instant of impact.
" v " " velocity
" η - Young's modulus for the material of the body C.

Then the fundamental law regulating the motion is
$$m\frac{dv}{dt} = -f$$
$$= -\eta\frac{a s}{l}$$
$$\frac{dv}{dt} = -\frac{\eta}{m}\frac{a}{l}s = \mu s \quad \text{say}$$
$$\frac{d^2v}{dt^2} = -\mu v$$
The solution of which is $v = \alpha\sin(t\sqrt{\mu} + \beta)$

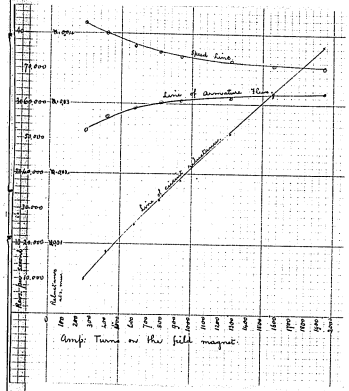
when $t = 0$ $v = V$ $\therefore\ V = \alpha\sin\beta$
$$\therefore\ \beta = \sin^{-1}\frac{V}{\alpha}$$
Also
$$\frac{dv}{dt} = \alpha\sqrt{\mu}\cos(t\sqrt{\mu} + \beta)$$
and when $t = 0$ $\frac{dv}{dt} = 0$ $\therefore\ 0 = \alpha\sqrt{\mu}\cos\beta$
$$\therefore\ \beta = \frac{\pi}{2} \qquad \therefore\ V = \alpha$$
$$\therefore\ v = V\sin\left(t\sqrt{\mu} + \frac{\pi}{2}\right)$$
$$= V\cos(t\sqrt{\mu})$$
Hence for $v = 0$
$$= 0$$
$$t\sqrt{\mu} = \frac{\pi}{2}$$
$$\text{or } \tau = \frac{\pi}{2}\sqrt{\frac{m l}{\eta a}} = \frac{\pi l}{2}\sqrt{\frac{\rho}{\eta}}$$

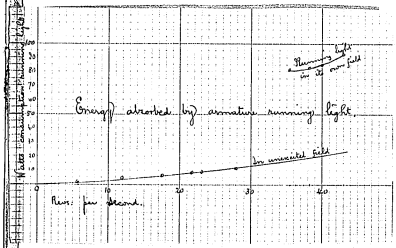
From which we deduce that the time of contact varies as the square root of the density directly, and the square root of the material Young's modulus inversely. Also if the body C were to oscillate between two such barriers without back lash, or loss of energy, its velocity would be a simple harmonic function of the time.

For a steel cube one cm. in length of edge, impinging against a rigid barrier the time of contact would be, assuming no loss of energy
$$\tau = \frac{\pi}{10^6}\sqrt{\frac{8}{3.14}} = \frac{6}{10^6} \times 10^{-6} \text{ second}$$

The time of contact should also be independent of the velocity.

In Book I. at pages 85-87 are recorded the results of some measurements made with spheres of different metals impinging upon a steel faced anvil. With spheres 2.5 in diam. the time was found to be practically independent of the velocity. Also the time of contact for such spheres was found to be with steel, copper, and zinc, to be 8.8, 11.1, and 10.3 $\times 10^{-5}$ respectively. $\sqrt{\frac{\rho}{\eta}}$ for these metals are $\sqrt{\frac{8}{3.14}}$, $\sqrt{\frac{8.9}{1.238}}$, 1.4 $\sqrt{?}$ that is 1.938 : 2.695 :: 8.8 : 12.25, and this is for steel against infinite rigidity and copper against infinite rigidity, instead of steel against steel, and copper against steel.


Dark line
Line of armature Volts
Line of energy absorbed
Amp: Turns on the field magnet.


Energy absorbed by armature running light.
Running light for 10 mm field
for unexcited field
Revs: per second.

Tests of 1/8 H.P. Motor after fitting with laminated polepieces.

The pole pieces are 2.5 wide radially, increasing to 2.8 near the extremities. They taper in thickness from 1.1 to 0.6, and they are each formed of 8 pieces, welded together in the centre.

The weight of the motor and ~~[illegible]~~ wooden base (pulley included) is 23 lb.

The resistance of the field (cool) is 0.97 Ω, it consists of 9 layers of 54 turns each (486 turns in all) of #18 S.W.G. 0.049" diam. to 0.065".

The inductance of the field is 83.24 with the armature in place.

The inductance of the armature in unexcited field is 4.126

The resistance of the armature coil averages 14.65 Ω. The brushes cover two bars of the commutator, and are of soft copper strips.

The following series of observations was made with varying excitation of the field coils. The motor running light. 122.5 lbs

No. of Obs.	Current in Field (Amps)	Amperes	Revolutions per min.	MMF Ats.	Flux thro armt. (1000)	Reluctance of circuit	Speed of armt. R. per sec.	Current in armt.	Energy in Watts	Energy per sq. inch
1	28°45'	3.975	1932	2439	63,400	3.83 x10⁴	2122	35.4	0.667	81.7
2	23°35'	3.230	1570	1974	63,180	3.12	2130	35.5	-	-
3	19°30'	2.620	1273	1600	61,980	2.58	2170	36.2	-	-
4	16°30'	1.91	928	1167	60,950	1.915	2210	36.8	-	-
5	12°15'	1.606	780	981	60,130	1.632	2238	37.3	-	-
6	9°30'	1.238	602	757	58,720	1.290	2293	38.2	0.677	82.9
7	6°20'	0.821	399	502	56,080	0.895	2402	40.0	0.693	84.9
8	3°25'	0.431	210	264	52,170	0.506	2580	43.0	0.755	92.5
	0.135									

	Energy per sq. inch
1	2.31
2	2.3
3	2.26
4	2.22
5	2.19
6	2.17
7	2.12
8	2.15

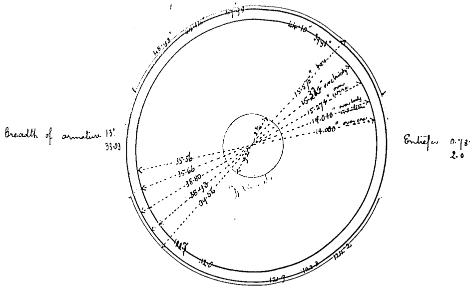
In calculating the flux through the armature, the no. of wire is taken as 396

The friction was then determined under various conditions

No.	Revolutions of armature per min	per sec.	Scale	Reading	Moment	Nominal	Energy absorbed	Energy per Revolution	Energy per sq. inch	Energy per sq. inch
	344	5.7.3	50 Ω	9.3	465	2.567 x10	1643	0.287		
	622	10.04		10.7	535	3.299	3.310	0.33		
	800	13.33		11.2	560	3.453	4.60	0.345		
	1045	17.4		12.9	595	3.668	6.38	0.367		
5	1300	21.7		12.3	615	3.793	8.23	0.379		
6	1380	23.0		12.8	640	3.946	9.08	0.395		
7	1670	27.8		13.8	690	4.255	11.83	0.426		

This last test was made with the brushes down but the field unexcited.

Cross Section of Drum Armature 1/4



Power. 25 HP. = 18.650 Watts @ 500 volt @ 85 % eff. 43.9 amp.
Speed Minimum at full power 800 revs: per min = 13.33 per. sec.
Dimensions
Drum armature. Wrought iron plates.

Breadth of core 13".	Core diam:	14.0"	35.56
Effective for magnetic conduction 10.4".	Body Ins.	14.04"	35.66
	Over wire	15.274"	38.80
	Over binding	15.324	38.93

Field. Wrought, and mitis cast Iron.
Length of cores 15". Breadth 13". Thickness 4"
Cross section 50 □in. = 322.5 □cms.
Armature Winding. 136 Sections, 136 Commutator blocks.
2720' of #10 B.W.G. 0.134" cond. D.CC. to 0.152". 818 c.m. per amp.
4 layers of 2 turns each in each section. 17,956 c.mils
544 complete turns. 1088 wires
Weight 150 lbs. circa
Resistance between brushes 0.4 ω hot.
Drop at full load in arm: 17.5 volts
Energy expended resistantly .. 768 Watts
Fiber divs: 136 of 0.015" each.

Field winding. (a) Multiple (b) Series. Mean turn 3.75'.
4 equal spools on each core 3.5" X 13.5". On copper 1/8" thick:
Free surface 6000 sq. cms. Surface per Watt. 15 sq. cms. per Watt
(a) Res: of each spool 1250 ω. 2 in series (one on each core) 2500 ω.
Current in each spool 0.2 amperes.
58 3/4 lbs. of #25 B.W.G. 0.020" cond: to 0.028" in 108 layers of 120 turns each
12,960 turns in all = 48,480' = 1250 ω. Depth of winding 3.5"
(b) Res: of each coil 68.75 ω (cool) = 78 ω hot. = 30.2 lbs:
of #20 BWG. 0.035" cond: to 0.043". Current in each spool 0.8 amp
27 layers of 75 turns = 2050 turns or 7690' of wire on each spool.
Depth of winding 1.5" on copper 1/8" thick.
Current in the field 0.9 amp. to 0.8
Energy expended . . . 450 . . 400 Watts.

Magnetic circuit. Cores 16,000 lines per sq: cm = 5.16×10^6 lines
Armature at full saturation 0.7 = 3.61×10^6. & about 5,000
Reluctance of cores 0.0025
entrefer 0.0030
armature 0.001
Total 0.0065 X (18.620 X 1.1 X 1.257) = 3.96×10^6

Torque = $1088 \times 43.9 \times 10^{-1} \times 3.61 \times 10^6 \div 6.28$ dynes = 2.746×10^9 = 2.80×10^6 gms.
= 2800 kgms. at 1 cm: rad. = 6170 lbs: @ 1 cm = 205 lbs: at a rad. of 1 ft
If the minimum speed of the car be 50 r.p.m of car (30") wheel, the power = 2020. lbs. at the car axle.

Copy of Determination sent to the Engineer-in-Chief.

Data of Electromagnetic Design, for a 25 HP. Street Car Motor
Power 18,650 Watts at 500 volts, and minimum speed of 800 revolutions per minute.
Current, allowing 85% efficiency, 43.9 amperes at full load.

Dimensions. Core	Armature Core diameter	14.0"
	over body insulation	14.04"
	Over wires	15.274"
	Over binding wires	15.324"

Breadth of armature core 13" (or 12 5/8" say)
Drum armature core of wrought iron plates, as in present Sprague type.
Field magnet of Mitis iron, yoke of wrought iron.
Core Breadth 13", Thickness 4".
Cross section nearly square. 50 sq. in.
Armature winding 136 sections, 136 commutator blocks.
2720' of # 10 BWG. wire 0.134", covered to 0.152"
area 17,956 c.mils. or 818 c.mils. per amp. at full load.
136 fiber divisions on armature edges 0.015" each.
544 complete turns round armature making 8 wires, (four layers of two turns each) in each section.
Weight of wire on armature about 150 lbs.
Resistance of armature between brushes 0.4 ohm. hot.
Drop in armature at full load 17.5 volts.
Energy expended resistantly in armature at full load 768 watts.
Field winding (a) Multiple series. (b) Simple series.
(a) 4 equal spools on each core.
Current in each spool 0.2 ampere.
58 3/4 lbs. of # 25 BWG. 0.020" cond. SCC. to 0.028" on each spool
Res. of each spool 1250 ohms. 48,480 feet. 12,960 turns
108 layers of 120 turns each.
Depth of winding 3.5" including cordage.
(b) 4 equal spools on each core. 30 lbs. of # 20 BWG.
0.035" SCC. to 0.043" on each spool 240 lbs. in all.
27 layers of 75 turns on each spool 2050 turns or 7690'
Depth of winding 1.5" including cordage. Spools 1/8th." thick (copper)
Resistance of each spool 78 ohms hot.
Energy in field at maximum current 0.8 amp. 400 watts.
Torque of motor 205 lbs. on armature shaft at rad. of 1'

Determination of the Winding for a 25 HP Street Car Motor, already alluded to on pages 38 + 52, to be made for the Engineering Department.

The entrefer in the Sprague #6 street car motor is given in Parshall's paper on the subject as 1.6 cms ($\frac{25.4 - 22.2}{2}$). The entrefer in the proposed dynamo might be increased 25% on this or to 2.0 cms. This is 0.787", so that retaining the armature diameter as 14", the bore of the field will be 15.575".

Of the entrefer, allow

clearance over all	0.125"
binding wire	0.025
body insulation	0.020
winding depth	#0.617"
	0.787"

With a cross section of 50 sq. in. in the core and mitis-iron, it would be possible to obtain 16,000 lines per sq. cm. and a total induction of 5.16×10^4 lines through the core, of which 60% will be useful, 3.1×10^4 lines will pass through the armature. Then 500 r.p.m. @ 500 volts = 13.33 r.p.s. and $w = 5 \times 10^8 / 13.33 \times 3.1 \times 10^4 = 1.21 \times 10^3$. Perhaps 70% might be expected in which case $p = 361 \times 10^4$ in which case $w = 1039$ say 1050. The mean diameter will be 14.638" mean cir. = 45.98" and the depth 0.617" = 28.38 sq. in. of winding space. $28.38/1050 = 0.02703$ = 0.164" cond. diameter allowing no lost space. (It will be actually necessary to use 4 layers each 0.154" cond. and allowing 0.015" for insulation gives 0.139" bare = #10 B.W.G. 0.134". 17,956 cm. which with 25 HP = 18,650 Watts @ 85% eff = 21,940 Watts = 21.94 amp. in the wire = 8.18 cms. per amp. On the winding circle 14 + 0.02 + 0.03 = 14.15" diam = 44.38" cir. there will be room for 292 wire each 0.152" say 280. There will then be 1120 wire in all 4 layers with fibre partitions 0.015" thick, and 128 commutator bars there will be 10 wire in 128 sections two wide and four deep. The breadth of each section = 0.319" and 128 of these make 43.38". There will then be 136 x 44 = 5984 turns on the armature. The length of each turn will be about 5' so that the resistance of all the wire will be 1.553 the res. between brushes, 0.388, the length of wire 5984 x 5 = 2720', the weight 146.8 lbs.

The poles area is 17.5 x 12" = 210 sq. in. = 1354 sq. cms. The reluctance of the air space is therefore 4/1354 = 0.00296 lucks. The length of iron circuit is 62" in the field = 157.5 cms of 322 cms x section = 157.5/322 = 0.49 x 0.005 = 0.0025 lucks. The reluctance of the armature is 35 ÷ 0.50 (32 x 35) = 35/640 ⅝ = 0.0547 x 0.002 = 0.001 luck. The total reluctance will thus be 0.0065 lucks. The mmfs for 3.6×10^4 is 23.4×10^3 = 18,620 AT. add 10% for arm. effect. = 20,500 AT.

The surfaces of the coils is 37 x 128 = 4735 sq. cms. ~~allowing~~ This does not include the interior surfaces facing each other. Allowing 15 sq. cms. per Watt, the available energy is 316 Watts say 400 ~~allow~~ including interior faces. ~~#~~ This gives 100 Watts per pair of quarter coils or 50 Watts per spool. The current will then be 0.2 amp. for each pair = 2500 ω or 1250 ω per spool. The A.T. per spool = 2500 = 12,800 turns. The mean perimeter is 42" = 3.5' so that the length = 44,800'. The length per ω = 35.84 = #28 B.W.G. The weight per ω = 0.047 lb. = 58.7 lbs. = 470 lbs. in all. The space occupied by this winding will be 2610 c.in. Single cotton covered, the bare diam. = 0.020" covered 0.028". Wound 0.03. The winding breadth = $\frac{128}{36}$ = 3.5 so that there will be 36 turns per layer. There will be 38.75 x 1250 = 48,400' = 13,200 turns of 3.65' = 1145 layers = 3.43" deep = 3.5" on reference. If wound in one series, the current = 0.8 amp. the total res. 625 ω = 500 ω cond. = 68.75 ω per spool. the turns = 2500 x 0.8 = 161,000 ⅝ = 2,050' = 7004 = 118,000 = #20 B.W.G. = 0.035" cond. to 0.043" = #18 = 75 turns per layer = 27 layers = 1.20" = 1.5 deep

Energy in brush friction
Energy in eddy + friction
Energy in Foucault currents
Ampère turns on field
0
10
20
30
40
50
60
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100

Calculation of a Series winding for the ½ H.P. motor as applied to 220 or 550 volts.

There are 1600 A.T. needed on the ½ H.P. field to practically saturate it. 600 A.T. would however be permissable, for light load. Supposing that it takes 50 Watts to run the motor light, then @ 240 volts the light current will be 0.21 amp. and consequently 3000 turns will be required. 600 Watts being the maximum intake = 2.5 amp. @ 240 volts the maximum drop allowed may be 10 volts. = ½ ω res: The mean diam: being 2.5" the mean circ: = 8" = 0.67' and 3000 turns = 2000' = 5000' per ω #13 wire say = 4 × 7.9 = 31 lbs. With 2500 turns, the length is 1670' and with 12.5 volts drop at full load of 2.5 amp. = 5 ω. = 3334' per ω. = #17 B.W.G. = 5 × 3.3 = 16.5 lbs.. With 2000 turns = 1333' = 15 volts drop at full load = 6 ω = 222' per ω. = #18 B.W.G. and 6 ω = 10 lbs. With 1500 turns = 1000' and 6 ω = 166' per ω = #19 B.W.G. and 6 ω = 5.4 lbs. This will occupy 30 cubic ins., or 10 sq: ins: per " of minimum length (3") = 4.0" externally.

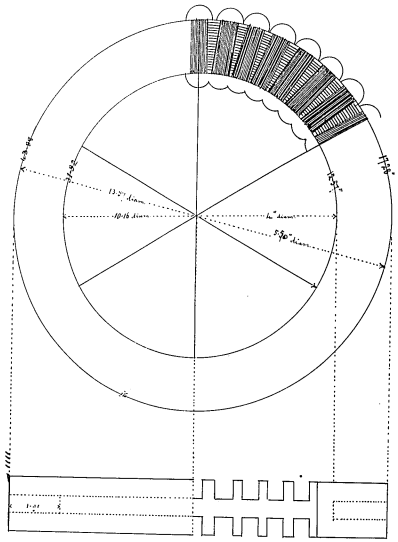
Tests of ½ H. P. Motor with laminated pole pieces.

The motor was balanced in the boat and was driven by the Mite ½ H.P. motor. The energy absorbed in overcoming mechanical and electrical friction was measured as follows:—

No. of Obs.	Speed of armature Revs. per sec.	Current Black	in the amperes	fields: Amp. turns	Moment of Balance Inches-lbs. (149850)	Energy Watts	Moment of Balance Inches-lbs	Energy Watts	Energy in mech. friction	Energy in brush friction	Energy in eddy current
1	27.8	0.0			899	14.5	375	6.3	6.3	7.8.2	0
2		0.081	0.422	205	1710	28.9	935	15.8	6.3	13.1	9.5
3		0.158	0.823	400	2365	40.	1770	29.9	6.3	10.1	13.5
4	Mean 27.4	0.245	1.276	620	2780	47.0	2110	35.8	6.3	11.3	18.1
5		0.322	1.678	815	3010	51.	2435	41.1	6.3	9.9	24.9
6		0.400	2.084	1013	3210	54.2	2590	43.8	6.3	10.4	27.1
7		0.565	2.944	1431	3395	57.35	2745	46.4	6.3	10.95	29.1
8	27.0	0.810	4.220	2051	3490	59.0	2935	49.6	6.3	9.4	33.9

By comparing these results with those recorded on page 48 taken with the same motor having solid pole pieces at 30 revs. per sec., it appears that the lamination of the poles has reduced the light load eddy current loss about 12 Watts or 25% at normal field excitation. This effect would probably be still greater for loads.

The greatest fault now existing in the motor was its noise, the passage of the teeth under the polar extremities, laminated as these were gave rise to a strong rattle or whir. To obviate this, it was decided to alter the shape of the pole pieces, so that instead of terminating radially they were cut off at an angle of 66° with the vertical. This had the desired effect. The rattle was reduced to an amount that could be tolerated.



PARTICULARS OF EDISON MODEL 1/16 HORSEPOWER MOTOR.

Weight on wooden base with pulley 14 lbs. 2 oz.
" fan 15 lbs.

Winding gramme-ring and series field.
Voltage 120 at machine terminals.
Amperes at delivery of 1/16th. HP. 1.4 amp.
Running light with resistance in circuit 0.38 amp.
Commercial efficiency at delivery of 1/16th. HP. 30%
Speed running light 4400 revs. per min. , but with resistance inserted, 2520 r.p.m.

Speed at delivery of 1/16th. HP. 2200 r.p.m.
Dimensions:-
Armature body , diameter external 5.5", internal 4.0"
Number of grooves 42 on each side.
Breadth of armature body over teeth 0.77"
at base of grooves 0.25"
Depth of grooves 0.26" , breadth 0.24"
Band iron in core 0.01" thick, wound in short lengths.
Cross section of armature core 1.2 sq. cms.
Breadth of teeth 0.21" at external, 0.06" at internal circle.
Insulation 0.003" mica at sides, 0.008" oiled silk on base.
Polar surface of teeth 12 sq. cms. under each pole.
Winding , 98 turns viz. 11 layers of 9 turns each of #28 BWG. wire covered to 0.024".
Commutator divisions 42.
Total length of wire on armature nearly 880 feet.
Total weight " " " "0.6 lb.
Resistance of armature between brushes including German silver connections 14.0 ohms cool and 15.4 ohms hot.
Current in armature at full load 1.4 amperes.
Drop in armature at full load 21.6 volts.
Energy expended in heating armature wire at full load 30 watts
Magnetic flux through armature section 15,000 C. G. S. lines.
Induction density in core space , (paper and iron) 12,500
Field magnet of Mitis cast wrought iron.
Pole pieces solid, and of wrought iron.
Core diameter 0.918" Inserflange 3.6"
Diameter over wire 2."
Flux through core center at full load. 60,000
Induction density of core at full load15,500
Winding about 3000 turns of wire # 24 BWG. 0.022" covered to 0.031". Two coils silk covered wire used, for want of proper size second
Resistance of field winding 25.5 ohms cool, and 28 ohms hot.
Drop in field at full load 39 volts. Energy 55 watts.
Resistance coil of german silver wire to reduce speed of motor on light load, wound over field magnet wire, 150 ohms of # 28 BWG gwire about 125 feet.
Total resistance of motor between terminals 190 ohms cool and 195 ohms hot including resistance.
Brushes of copper gauze to cover two blocks of commutator.
Connections from armature to commutator g.s. 0.0005"5.1 ohms

On the Electromagnetic Design of a 1/16 H.P. Motor (50 Watts)

to be constructed on the same general plan as that of the larger size, but with resistance in the circuit to reduce the pressure on the armature to 60 volts. The armature to be also reduced in diameter.

In the 1/8 H.P. motor there are 5,460 turns on the armature, the flux is 62,000 nearly. The speed 2100. The intake at full load 300 Watts. Supposing the maximum intake on the new motor reduced to 200 Watts, of which 50 Watts had to be delivered by the shaft.

Allowing 12,500 lines per sq. cm. of core cross section (paper and iron) the area must be 30,000 ÷ 12,500 = 2·4 sq. cm. = 1·2 sq. cm. on each side. The depth being 1·905", the width must be 0·63 cm. = 0·248" say 0·25".

The same number and width of grooves as in the 1/8 H.P. model. Big 42 grooves each $\left\{\begin{matrix}0.7\\0.46\end{matrix}\right\}$ deep and $\left\{\begin{matrix}0.7\\0.46\end{matrix}\right\}$ wide. Total Breadth $\frac{25}{32}$ = 0·777".

Toe of ridge $\left\{\begin{matrix}0.0592"\\0.15\end{matrix}\right\}$ Heel of ridge $\left\{\begin{matrix}0.777\\0.2024\end{matrix}\right\}$

Speed with 60 volts on the armature, running light 36·6 revs. p.s or 2196 revs. per min. Perhaps 3500 when light.

The area of one side of the armature is 72·2 sq. cm. of which 56 lie in the grooves leaving 16·2 for the teeth = 0·386 sq. cm. for each tooth. If such teeth are always under each pole surface on each side, or 32 in all = 12·34 sq. cm. of surface constituting each pole. B in the teeth = 2,730. The reluctance of the air gaps is $\frac{2 \times 0.05}{12.34}$ = 0·013

$\frac{g}{2}$ cm. of iron: 1·2 sq. cm. @ 15,000 $\frac{4.5 \times 0.002}{1.2}$ = 0·0075

Reluctance of armature. 0·0205

The resistance of the armature if wound with the same wire as that on the 1/8 H.P. is 0·0155" s.c.c. to 0·0285", or even if it be wound with 0·014" wire (# 28 B.W.G.) mean 0·022", the res. of the armature will be about 14 ω. The energy wasted in the armature will be say 50 Watts

The cross-section of one of the mitre iron legs is to be 0·3 sq. in. The breadth is 0·5", the width 0·75", it is required to find the radius of curvature which allowed to smooth off the edges will bring the section to the right amount. This will be when

$$\pi r^2 + (0.5 - 2r)2r + (0.75 - 2r)0.5 = 0.3$$
$$3.145r^2 + r - 4r^2 + 0.375 - r = 0.3$$
$$-0.86r^2 = -0.075$$
$$-r^2 = -0.0872$$
$$r = 0.295"$$

Weight of the iron armature core & spider 620 gms.

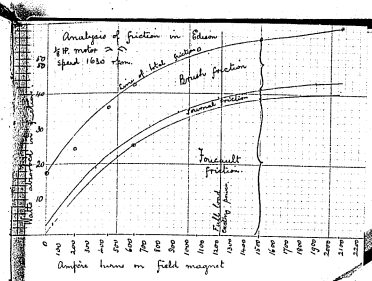
Thickness of the iron band 0·01"

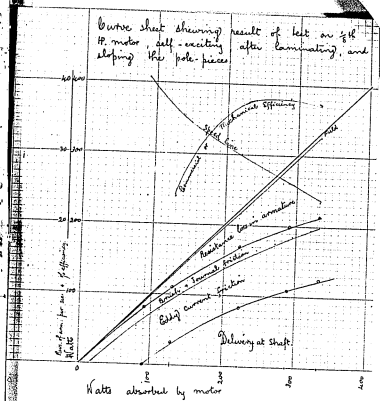
The experimental winding of the 1/16 H.P. field was 14 layers of 66 turns each # 19 B.W.G. = 924 turns.

Weight in completion 15 lbs.

The armature was wound with 11 layers of 9 turns (99 turns in all) in each groove as the covering of the wire was too thick to allow of more than this. Total wire all round = 4158

No. of Obs.	P.D. on motor	Current in motor (Board)	Ampere	Energy in motor	Current in field Amperes	Ampere turns on field	Energy in field $\frac{E^2}{R}$	$\frac{E^2}{R_{(2)}}$	Energy in armature	Calculated shaft in armature	E.M.F. generated by armature	Speed of armature R.p.m.	Torque lb.ft.
1	122.25	0.120	0.625	76.5	1.73	8241	1.7	2.0	76.5	9.37	112.8	2280	38.0
2	"	0.195	1.015	124.2	"	-	-	-	124.2	15.2	107.	2085	34.75
3		0.342	1.781	218.1	"	-	-	-	218.1	26.7	95.5	1812	30.2
4		0.460	2.396	293.4	"	-	-	-	293.4	36.0	86.3	1610	26.8
5		0.540	2.813	344.5	"	-	-	-	344.5	42.1	80.2	1415	23.6
6	122.25	0.141	0.734	89.9	0.734	357	0.73	0.58	89.4	11.0	110.6	2450	40.8
7		0.200	1.042	127.6	1.042	507	1.04	1.08	126.5	15.6	108.7	2120	35.6
8		0.348	1.813	222.1	1.813	881	1.81	3.28	218.9	27.2	93.3	1800	30.0
9		0.458	2.386	287.1	2.386	1139	2.38	5.68	281.6	35.2	87.6	1565	26.1
10		0.522	2.719	333	2.719	1321	2.72	7.40	325.6	40.8	78.5	1410	23.5





Tests of the ⅛th. H.P. Motor after tapering off the pole pieces. 8th Jan. 31.

First test, for determining the natures, and degrees of friction. Motor unbalanced in boat, and run by the Mitis non ⅛ H.P. motor.

Speed of Motor r.p.minute	r.p.sec.	Current in Armature Ohmic	Amp.ferm	Field Amp.ferm	Scale 50 grams	Reading Moment	Energy absolute	Condition	Energy energy	Total friction
1620	27.16	0	-	-	3.2	160	2.68	Brushes off	-	17.4
-	-	0.082	0.427	207	11.2	560	9.4	-	6.7	24.6
-	-	0.175	0.911	443	25.2	1260	21.1	-	18.4	35.8
-	-	0.248	1.290	627	32.9	1645	27.6	-	24.9	42.3
-	-	0.333	1.735	843	50.3	2515		-		
-	-	0.42	2.187	1063	44.8	2240	37.5	-	34.8	52.7
-	-	0.592	3.083	1498	48.7	2435	40.8	-	38.1	58.5
-	-	0.820	4.270	2075	51.9	2595	43.5	-	40.8	58.7
-	-	0	-	-	20.8	1040	17.4	Brushes lifted	-	17.4
-	-	0.820	4.270	2075	69.3	3465	58.0	-	40.6	98.0

For the plotted curve of these results see p. 57. as well as opposite.

Second Test for efficiency. The ⅛ H. motor, driving the mitis ¼ H.P. as dynamo.

Time [illegible]	Bench Reading grams	Q	Moment	Moment ×216	Watts delivered by shaft	Effort	Effort — Efficiency (friction)	Mechanical Efficiency	Electrical Efficiency.
.97	-	-	-	-	-	70.5	70.5	-	0.922
.08	[50 @ 3.2; 100 @ 10]		1110	6.842×10^6	23.8	108.6	84.5	0.192	0.875
.16	[50 @ 10; 100 @ 15; 100 @ 25]		4400	2.467×10^7	74.5	170.1	95.6	0.342	0.780
.22	[100 @ 25; 100 @ 35]		6500	4.009 -	107.5	206.7	99.2	0.367	0.705
.40	[50 @ 25; 100 @ 35; 100 @ 45; 100 @ 55]		8840	5.451 -	128.7	225.6	96.9	0.281	0.655
.71	-		-	-	-	81.2	81.2	-	0.903
7	50 @ 10; 100 @ 25		1400	8.63×10^6	20.7	180.1	79.4	0.261	0.863
"	100 @ 20; 100 @ 35		4500	2.775×10^7	33.25	169.2	86.	0.375	0.762
4	100, 100 @ 15, 100 @ 25		6800	4.193 -	109.4	198.3	88.9	0.381	0.691
15	100 @ 1, 100 @ 15, 100 @ 25, + 200 @ 10		8550	5.272 -	123.9	214.3	90.4	0.372	0.644

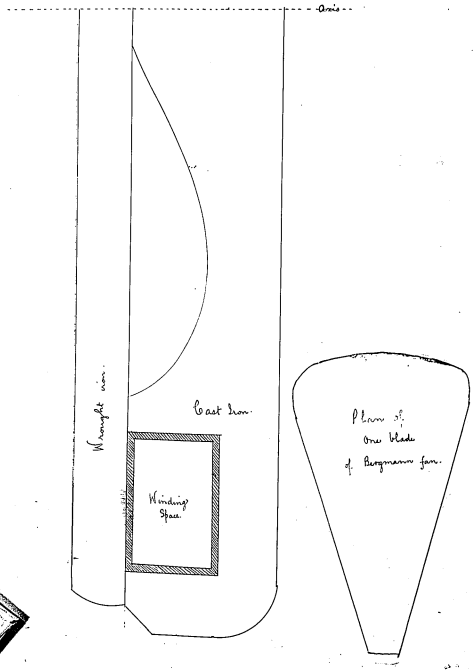
The exciting power necessary to saturate the armature was then determined as follows — separate excitation.

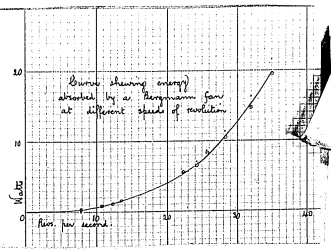
No. of Obs.	P.D. on Motor	Ohmic	Current thro' motor	Drop in armat.	EMF generated by motor	Ring Component	Amp.	Amp. ferm	Speed of R.p.m.	armature R.p.sec.	Calculated Flux
1	122.5	0.140	0.729	10.9	111.6	-	0.427	207.5	2516	41.9	48,780
2		0.130	0.677	10.2	112.3	0.1154	0.854	415	2448	40.8	50,430
3		0.115	0.599	9.0	113.5	0.1808	1.339	651	2380	39.7	52,350
4		0.120	0.625	9.4	113.1	0.2217	1.642	798	2299	38.3	54,080
5		0.110	0.573	8.6	113.9	0.2851	2.112	1027	2244	37.4	55,800
6		0.105	0.547	8.2	114.3	0.3895	2.773	1834	2163	36.0	58,150

For the plot of these results see the dotted line on the curve sheet of p. 46. (infra.)

The result of slotting away the pole pieces has therefore been to increase the efficiency for the same excitation about 5% or reduce the armature flux about 5%, to greatly reduce the noise of the motor operation, and to slightly reduce the frictional losses (about 3 Watts) and the brush sparking. Altogether a marked improvement.

Cross Section of Electromagnetic clutch taken through the axis. Full size.





Calculation for the dimensions of a clutch to transmit the power of the Edison #2 street Car Motor direct on the same axle.

The Edison #2 d.c. Motor has to exert 22·5 kwts: at full load = 16,600 ft lbs. per second: ; and the speed being 4 revs: per sec: = 4,150 ft lbs. per rev. ~~the~~ radius + (pitch) the pull is $\frac{4150}{2\pi r}$ lbs. weight = $\frac{660.5}{r}$

This pull is divided between two clutches, so that the moment of each is 330 ft × lbs wt. The clutch described at page 126 Book III had a moment of 1300 ft × lbs wt. with 4·3 amperes. The clutch to be designed must operate effectually at 5 amperes and not overheat at 50. Each clutch must not exceed 0·125 w resistance.

Taking the mean radii of action as 8·3" and 5·75" = circ. of 52·1 and ~~5~~ 36·1" inches. Each 0·5" hood = ~~16·6~~ sq: inches of surface or 26 sq: in: acting at a rad: of 8·3" and 18 sq: in: acting at a radius of 5·75. Assuming $S = 16,000$ $S^2 = 2.56 \times 10^8 + \frac{S^2}{8} = 10^7 = 1000$ p = 22 lbs: per sq: cm: = 140 lbs. per sq: in , allowing say) 100 lbs. per sq: in: the moment expected will be 2600 × 0·7 + 1800 × 0·48 = 2684 ft × lbs. wt. With $S = 8,000$ (cast iron) we should still have 900 ft × lbs. weight

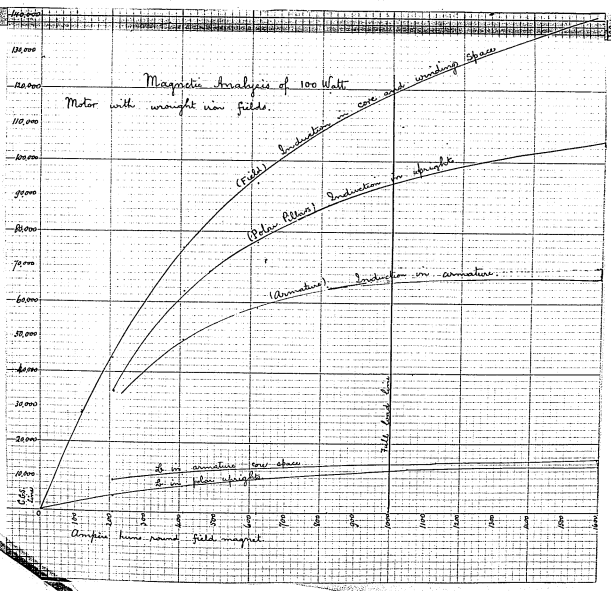
The mean radius of the winding = 7", and the cross section is 1·8 sq: in: The total volume is thus 44·4 × 1·8 = 79·2 sq cubic in = 14·4 lbs. This must have a res: of 0·12 w or 0·00833 w per lb. ~~#~~ 9 B.W.G. Diam. 0·148 = 0·160" covered six layers of 11 turns = 66 turns = 247·5', The ampere turns at light load will be 320, the mmF 410. With 0·05 cm: air space, the reluctance per sq: cm: would be 0·05, and the flux 82,00.

Test of the power taken in revolving a Bergmann fan at different speeds. 10th Jan. 91.

This fan has four blades at right angles. They planes make an angle of 25° with the plane normal to the axis, except one which makes about 31°. They are made of sheet brass 0·032" thick. The tip to tip diam is 23, and the greatest breadth is 6·45. The outline is represented on the opposite page. The 1/8th H.P. motor was floated, and the fan was driven by a flexible coupling to the fan armature shaft. The brushes of the fan motor were lifted, and the fields left unexcited.

Speed of Armature r.p.m.	Speed of fan r.p.m.	Speed of motor r.p.s.	Balances 50 @		Moment	6165 × Moment	Actual Energy Watts	Remarks & Speed Ratio	Cubic proportion
20	408	6·8	torque	8·2	60	3.70×10^5	0·25		
47·5	646	10·8	-	2·3	115	7·09	0·77		
54	734	12·2	-	2·7	135	8·32	1·02		
59·5	809	13·5	-	3·5	175	1.079×10^6	1·46		
98	1333	22·2	-	8·0	400	2·467	5·48	Stations	Stations
107	1455	24·25	-	8·9	445	2·743	6·65	1·0925	7·16
114	1550	25·8	-	10·3	515	3·175	8·2	1·162	8·60
125	1700	28·3	-	11·8	590	3·638	10·3	1·275	11·96
141	1918	31·97	-	15·0	750	4·624	14·77	1·24	16·37
155	2108	35·1	-	18·05	903	5·567	19·54	1·351	21·66
155	2108	35·1	-	27	1350	8·324	29·2	Board held in front of fan stopping the flow of air.	

The work done by the fan varies approximately as the cube of the speed.


Magnetic Analysis of 100 Watt
Motor with wrought iron fields.
(Field) Induction in core at winding space
(Polar Pieces) Induction in uprights
(Armature) Induction in armature
B in armature tow shaft
B in pole uprights
Field Lines
Ampere turns round field magnet.
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
120,000
130,000
140,000

Magnetic tests of ½ H.P. Motor after stepping polar extremities 9th January 1891.

Five turns of insulated wire were wound upon (1) the field magnet centre (2) the four upright legs 3 the armature above and below midway between the poles, and the extremities taken to the ballistic galvo.

Test No.	Sample in field at	Obsch	Current	Amp turns	MMF	Mean Ohms ×10 ⁶	Q	φ	B	Dimensions	2B and φ.
	1	0·081	0·422	205	257·6	67	$8·38 \times 10^{-7}$	44,000	5,580	Diam	
	2	0·162	0·844	410	515·3	115	14·39 -	75,560	9,580	1·25" diam:	
	3	0·245	1·276	620	779·2	143	17·9 -	93,960	11,910	= 7·89 □	
	4	0·325	1·693	823	1034	166·8	20·86 -	109,500	13,880		
	8	0·65	3·385	1645	2067	212	26·52 -	139,200	17,660		
	1	0·081	0·422	205	257·6	27·5	$3·44 \times 10^{-7}$	18,060	4,588	2·5 in Diam	9,098
	2	0·162	0·844	410	515·3	49	6·13 -	32,180	8,174	× 1·25 -	12,946
	3	0·245	1·276	620	779·2	59	7·38 -	38,750	9,844	= 3·927	19,984
	4	0·325	1·693	823	1034	67	8·38 -	44,000	11,180		22,360
	8	0·65	3·385	1645	2067	78·5	9·82 -	51,500	13,080		26,770
	1	0·081	0·422	205	257·6	24	3·00 -	15,750	4,000		8,666
	2	0·162	0·844	410	515·3	43	5·38 -	28,240	7,174	"	15,844
	3	0·245	1·276	620	779·2	53	7·01 -	36,800	9,348		19,698
	4	0·325	1·693	823	1034	63	7·88 -	41,380	10,510		22,110
	8	0·650	3·385	1645	2067	77·5	9·70 -	50,920	12,940		26,620
	1	0·081	0·422	205	257·6	28	3·50 -	18,370	4,666		34,180
	2	0·162	0·844	410	515·3	52	6·50 -	34,130	8,670		62,370
	3	0·245	1·276	620	779·2	62	7·76 -	40,740	10,350	"	77,540
	4	0·325	1·693	823	1034	69·5	8·70 -	45,670	11,600		87,050
	8	0·650	3·385	1645	2067	82	10·26 -	53,860	13,680		104,780
	1	0·081	0·422	205	257·6	27	3·38 -	17,750	4,510		35,810
	2	0·162	0·844	410	515·3	47	5·88 -	30,870	7,842		63,050
	3	0·245	1·276	620	779·2	60	7·51 -	39,420	10,010	"	78,170
	4	0·325	1·693	823	1034	67	8·38 -	44,000	11,180		89,000
	8	0·650	3·385	1645	2067	82	10·26 -	53,870	13,690		105,370
	1	0·081	0·422	205	257·6	31	3·88 -	20,370	5,174	Diam:	16,864
	2	0·162	0·844	410	515·3	37	4·63 -	24,310	6,170	× Section	22,450
	3	0·245	1·276	620	779·2	44·5	5·56 -	29,190	7,390		26,640
	4	0·325	1·693	823	1034	46	5·75 -	30,190	7,670	2·150 □	27,720
	8	0·650	3·385	1645	2067	51	6·38 -	33,490	8,510		30,580
	1	0·081	0·422	205	257·6	25	3·13 -	16,430	7,520		36,800
	2	0·162	0·844	410	515·3	37·5	4·69 -	24,620	11,300	Diam.	48,930
	3	0·205	1·276	620	779·2	44	5·50 -	28,870	13,250	2·150 □	58,060
	4	0·325	1·693	823	1034	46	5·76 -	30,240	13,870		60,430
	8	0·650	3·385	1645	2067	50·5	6·32 -	33,180	15,220		66,670

Test No.	Source of E.M.F.	E.M.F.	Capacity	Q.	Mean Throw	Q. per unit dist.
	1 G.C. @ 20°·0	1·4325	2	$2·865 \times 10^{-7}$	22g	$1·281 \times 10^{-3}$

[illegible]	[illegible]	[illegible]	[illegible]
16·5	1	[illegible]	7·2
[illegible]	[illegible]	10	9
[illegible]	[illegible]	[illegible]	0·017
[illegible]	[illegible]	[illegible]	100,000
[illegible]	[illegible]	1·075"	[illegible]
[illegible]	[illegible]	150,000	[illegible]
[illegible]	[illegible]	15,000	[illegible]
3,000	1,550	550	[illegible]
1·4	1·5	3·	[illegible]
[illegible]	1·0	[illegible]	550
[illegible]	1·20	[illegible]	[illegible]
3	1·0	2·0	1·0
[illegible]	1·6	[illegible]	[illegible]
0·035"	0·065"	0·051"	0·015"
25	8	10	6·0

Resumé of Dimensions of Small Model Motors.

Dimension	½ HP 5.0 Watts (Scripps motor) 14 lbs	¾ HP 100 W/lb (Scripps motor) 22 lbs	¾ HP 200 W/lb 18 lbs	¾ HP 400 W/lb 16 lbs	1 HP 800 W/lb	1½ HP 225 W/lb 1200 Series 37 lbs
Armature: Ext. diameter	5.5" 139.7	6" 152.4	6" 152.4	6" 152.5	7" 177.8	6"
" Int. "	4" 101.6	4" 101.6	4" 101.6	4" 101.6	4.5" 114.3	4"
" No. of grooves	42	42	42	42	42	42
Extreme breadth	.077"	0.406" 2.30	1.182"	1.45"		1.45"
Bore breadth (Cross section)	0.25" 1.2	0.344" 0.87	0.661" 1.69	1" 2.54	1.25" 3.16	1" 2.54
Depth of groove:	0.26 0.66	0.28 0.71	0.26 0.66	0.225" 0.57	1.50" 10.16	1" 2.54
Breadth " "	0.24" 0.6	0.21" 0.61	0.24 0.61	0.225" 0.57	0.375	0.225
Weight - armature core	6 oz. (with spider)			6 lbs.		0.26
Polar surface on teeth	12 □ cm	20 □ cm	20 □ cm	32 □ cm	42.3 □	26 □ cm
Number of turns per groove	99 4/158	130	72	49	30	90
Layers.	11	13	9	7	6	9
Diam. of conductor	0.0114"	0.0155" 0.039	0.019"	0.018"	0.022"	0.016
Covered diam.	0.024"	0.0225" 0.057	0.0265"	0.029"	0.050"	0.023
Body insulation	0.01"	0.008" 0.020	0.010	0.01"	0.01	0.01
Thickness of iron core strip	0.1"	0.029" 0.074	0.029"	0.029"		0.017
Commutator divs:	42	42	42	42	42	42
Length of wire on armt.	980'	1500'	1008'	910'	845'	1860'
Weight - - -	0.6 lbs.	1.15 lbs	0.99	0.94 lbs	2.5 lbs	1.1 lbs
Res: of armt. between brushes	14.2.5 15.4	16.0 w 1.04 Ohm 17.75 w 1.19	8.0 0.455 9.2 w 0.64	8.2 w 8.2 w	1.25 1.2	22.5 22.5
Current in armt. at full load (Rated)	1.43	1.39	3.33	4.5 amp.	11.1	2.73
Drop - - - - -	21.6 w	26.6	30.7 .82	37.5 volts	24 w	60 v.
Energy - - - - -	30.2	40	102.1	170 watts	222	162
Flux thru armature half	15,000	30,000	55,500	100,000	150,000	100,000
mean B in core approx.	12,500	13,760	13,000	15,000	15,000	15,000
Diameter of core. Width (Metric)	.8875" 2.23 0.918" 2.33	1.25" 3.175 1.4" 3.55	1.6" 4.06 1.675" 4.25	1.875" 4.76	2.5" 6.35 2.47 6.7	2" 5.08
Interflange.	3.6 9.2	4 10.2	4" 10.2	4"		3.8"
Diameter of wound core	2" 5.1	2.28 5.8	3.04" 7.72	2.5"		3.25"
Area of core. Width in	3.87 4.26	1.27 7.89 1.42 9.0	4.05 12.9 4.42	2.75"	4.91 31.7 5.06 32.65	3.14" 20.2
Flux. (full load)	60,000	120,000	200,000	285,000	300,000	320,000
B in core. (full load)	15,500	12,120	15,500	16,000	16,000	14,000
No. of turns on field	3090	450	660	7630		806
Current thru field with (Rated)	1.43	1.54	3.33	0.294 0.296		2.73
Amp. Turns (full load) (Rated)	4200	675	2240	1,700 1,830		2176
M.M.F. (Rated)	5280	849	2750	2,130 1,910		2736
Energy in field	55 w	2.8 w	26 w	27.4		27.0
Res: of field (Rated)	25.45 27.90	1.0 1.2 w	2.3 2.4 w	550 w 600 w		3.5 3.90
Drop in field (full load)	29.1	1.8 v.	8.8 v.	120 volts		10 v.
Weight of wire	1.6 lbs.	1.62 lbs	2 lbs.	3.6 1.7 lbs		3.2 lbs.
Bare diameter wire	0.022"	0.049"	0.062"	0.01"		0.0122" 0.300
Covered - -	0.031"	0.065"	0.078"	0.015"		0.051"
Layers.		8	10	60?		13
Speed of armature R.p.m.	4000 to 2200	2900 to 2000	2,500 to 1,100	1700 to 1300	1700 to	3000 to 1500
R.p.s.	73.3 36.7	48.3 - 33.3	41.7 23.3	28.3 - 21.7	21.3	50 - 25

Electromagnetic Design for a ¼ HP (200 Watt) Edison motor for 120 volts 3.3 amp. 11th Jan.

Power 200 Watts at full load. delivered by shaft
100 - lost - - - in armature
90 - - in friction + foucault currents
390 - intake at full load = 3.25 amp. @ 120 volts.

Speed 2050 revs p. min: at light load, but strong field, and finely laminated armature.

Armature Dimensions

External diam.	6"	15.24
Internal -	4"	10.16.
Extreme breadth	1.182"	3.00
Core -	0.662"	1.68
Grooves	42	
Depth of groove	0.26"	0.66
Breadth -	0.24"	0.61

Winding
72 wires in each groove
9 layers of 8 turns each.
Body insulation 0.01" 0.025"
Space 0.22" broad 0.25" deep.
Wire # 26 B.W.G. 0.018" covered to 0.0265
Space occupied 0.242" broad 0.239" deep.
42 Commutator bars
Length of wire 1008'
Weight - - 0.99 lb.
Res - - 32 ω = 8 ω between brushes 9.2 ω hot

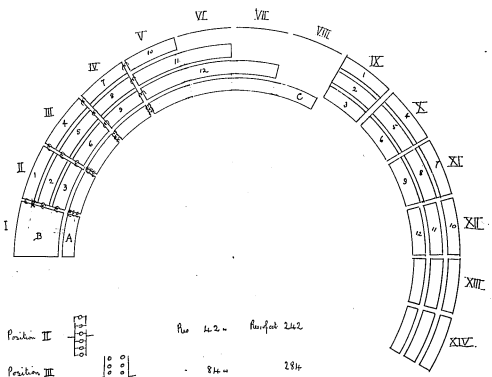
Drop in armature at full load 30.7 volts
Energy - - - - 102 Watts.
Flux through semi ring 55,500
Total useful flux 111,000
Mean ⌀ in core space (4.27)' = 13,000

Field. Allowing a total flux of 200,000 and a mean density of 15,500, the wrought iron core diametric area = 12.9 □ cm.
- mitis iron - - = 14.2 □ cm.

The wrought iron diameter = 4.05 = 1.595" or 1.6" say
mitis - - = 4.25 = 1.673" or 1.675".

The trial field winding may be 2 lbs: of copper wire having a res: of 1 ω = 0.5 ω per lb. = # 16 B.S. or # 18 B.W.G. preferably. The turns = 500'. The mean diameter being 2.1", the mean circ: = 6.55' or with mitis iron 6.6' = 880 turns = 12.0 layers of 69 turns = 0.72" depth of winding = 3.04" extr. diam.
For outline of armature, see the sketch for ½ HP p. 26 which is correct representation for this armature in all but breadth of core proper.
9 layers of 50 turns each on the experimental field-winding

Horse Power		Cabin Old pattern	Cabin New pattern	Perret	Sommer July 1890	Ansonia Feb	Connecticut	Rider	Detroit	Goodwin	Sprague	G+R	Sanborn March
	Revs. per min		2400 1200	2500 - 220		2000						3000	2100
	Voltage		120	120		110						110	110
	Net weight		20	17½		15						18	25
½	Floor space		7½×7½×10	7½×7½×10									9⅞×7⅞×11
	Pulley			1½"									
	List price		$60	$32		$32							$32
	Revs. per min	2100	2500 1400	2000		1500			2400		2000		1500
	Voltage	110	120	55 6 120		110 + 220			110		110		110
½	Net weight	90	29	50		45			72		52		65
	Floor space	16½×13½"							6"×14"		14½×11½"		14⅞×8⅞×11½
	Pulley	3½×2×½"		2"×					2"×2"		2"×1½"		3×2
	List price	$65.69	$100	$90.		$90			$90				
	Revs. per min	2100	1700 6 1200	2000	3000	2500	2000	2400	2200		1900		1400
	Voltage	110	120 440	25 6 120		110 + 220	110	55 6 220	110		110		110 - 220
¾	Net Weight	120	36	70	130	70	130		114		130		94½
	Floor Space	22½×16½		?	5½×7½"		14½×16½		7½"×18½"		25½×17½"		18½×11×11"
	Pulley	5½×2½×½		2½"	3"×1½"		5½"	3"×2"	3"×2"		2½"×2"		3½×3"
	List Price	$103.25	$125 3 pt 75 L pattern	$130		$120	$130	$120	$130				$130
	Revs. per min	1800	1500 6 1050	1800		1500	2000	1500	2000	2100	1800		1300
	Voltage	110	120 240 500	60 6 230		110 + 220	110	55 6 220	110	110	110		110 - 220
1	Net Weight	270	113	182			250		180	137	202		157
	Floor space	24½×22½	14½×16½×10½	22½×16½×18½			14½×16½		8½×22"	14"×22"	25½×17½×18½		22½×12½×17
	Pulley	4½×5×½"	4½×2½×½	4½×½		4"×	4½×2½	4"×2"	4½×2½"	4"×2"	4½×2½"		4×4
	List Price	$159.25		$160		$150	$160	$150	$160	$160			$160
	Revs. per min.			1500		1400	1800	1500	1900	2000	1650		1290
	Voltage			60 6 230		110, 220, 500	110	55 6 220	110	110	110		110 - 220
2	Net weight			200			450		292	270	329		290
	Floor space						16½×16½"		9½"×24½"	17"×19"	25½×17½×18½		22½×17½×18½
	Pulley			4"		6"	5½×3"	5"×2½"	5½×3½"	5"×2½"	5"×3"		6×3
	List Price			$200		$200	$250	$200	$250	$250			?
	Rev. per min	1475											
	Voltage	125											
2½	Net Weight	550											
	Floor space	22½×22½											
	Pulley	7½×5×½											
	List Price	$282.75											



		Res	Res. for 60	242
Position II		42 ω		
Position III		84 ω		284
Position IV		125 ω		325
Position V		167.5 ω		367.5
Position VI		200 ω		400
Position VII		250 ω		450
Position VIII		333 ω		533
Position IX		416 ω		616
Position X		500 ω		700
Position XI		583 ω		783
Position XII		666 ω		866
Position XIII		750 ω		950
Position XIV		833 ω		1033

Test of the Carrying Capacity of Six Switches on porcelain bases, received from the Newyorth Works.

10th Jany. These switches were as follows.

#1	One	120 light	switch double pole
#2	One	60	- - - -
#3	One	30	- - - -
#4	One	15	- - - -
#5	One	10 ?	- - - -
#6	One	10 ?	- - two way & single pole.

The 120 light switch was used with 126 lamps (56.25 amp) successfully, ~~but~~ for five minutes without any appreciable heating and no dangerous spark. If used however as a single pole switch so as to break the circuit at one opening or pair of springs, the arc followed up, and remained for a little while.

The 60 light switch was used with 30 lamps (38.03 amp) successfully without overheating or dangerous sparking.

The 30 light switch was used with 50 lamp (20.84 amp) successfully and even with 100 lamps without any difficulty.

The 15 light switch was used with up to 65 lamps on.

The 10 - - - - - - 50 - -

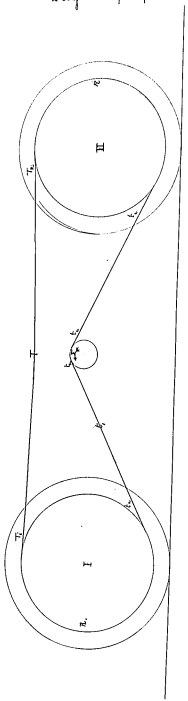
The 10 - 2 way - - - - - 5 - -

Design for a Lamp Resistance in the field circuit of the No 2 Car Motor.

Allowing 110 volt lamps of 16 cp and 0.45 amp = 245 ω res: hot say 250 ω at working temp. With these data we have the following table :-

No of Point	Group	Res.	Total res in cct.	Current @ 550 volts	Current per lamp	Res: of one series of lamps fed	Total res in cct.	Current per lamp	Res of two series of lamps fed	Total Res in cct.	Current per lamp
II	1 of 6	42	242	2.066	0.3442	50	250				
III	2 . 6	84	284	1.760	0.280	100	300				
IV	3 . 6	125	325	1.538	0.256	150	350				
V	4 . 6	167.5	367.5	1.363	0.227	200	400				
VI	5 . 6	200	400	1.250	0.250	250	450				
VII	6 . 6	250	450	1.111	0.278	333	533				
VIII	4 . 3	333	533	0.938	0.312	500	700				
IX	5 . 3	416	616	0.822	0.271	625	825				
X	6 . 3	500	700	0.714	0.238	750	950				
XI	7 . 3	583	783	0.639	0.213	875	1075				
XII	8 . 3	666	866	0.578	0.193	1000	1200				
XIII	9 . 3	750	950	0.527	0.176	1125	1325				
XIV	10 . 3	833	1033	0.484	0.161	1250	1450				
XIV											

Diagram of Sprocket chain and pulleys.
Scale 1" = 1 foot.



Problem:- To determine the power capable of being exerted by a sprocket chain on the car.

The tension on the belt between the large pulleys is that due to the catenary pull due to a given sag, and weight of belt per foot. The tension on the lower halves may be approximated to as $\frac{3}{4}$ths on the convex suspension and $\frac{1}{4}$th on the outer suspension of the catenary pull if level.

Let F be the pull delivered to the belt by the armature in lbs. weight
t_1, t_2 . . catenary pulls on the belt at point of union with pulleys
T_1 T_2 . . . . . above . . . . . .
μ . . coeff. of friction between belt and pulley.
R_1, R_2 . . resisting forces of the car against the chain.

Then the driving condition for R_2 is

$$R_2 = F + t_2 - T_2$$

Since the arc of embrace is about 195°,

$F + t_2 = 2.03 R$ $T_2 = 1.03 R$ for iron upon iron
$F + t_2 = 1.35 R$ $T_2 = 0.345 R$ - - - wood.

The pull $F = \frac{2500}{2} = 1250$ lbs.
so that $T_2 = 1200$ lbs for iron upon iron
and $T_2 = 430$ - - iron - wood.

The weight of the chain is 8.7 lbs. per foot. = 26 lbs. per half span
For iron against iron $T_2 = 50$ ~~feet~~ times the half span weight
- - - wood $T_2 = 16$ - - - - -

Determination of Obach and Standard Galvanometer Constants
14th Jan. 91

Copper electrolytic cell. Plates 13.8 x 7.6 immersing 68.5 sq. cm. on each side. in solution of $CuSO_4$ sp. g. 1.10 @ 17°C

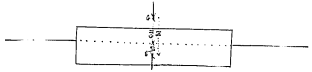
	Weight of Plates before test	Weight of plates after test	Gain	Loss	Accepted transfer	Time of test, Seconds.	Mean Tangent	Accepted mean current	Tan. per amp	Maximum possible error	Amp for Tan 1.
A	39.3090	38.6375	0.2285		0.2275	585	0.321616 obach	1.708~~12~~ amp	0.18907		~~0.529~~
B	39.2265	38.9018		0.3247	=0.005615 per sec						
A+B	77.5565	77.5390					2.07836	~~1.2280~~	~~1.2280~~		0.81143
Sum	77.5565	77.5393									making R = 0.202

Pressure measured at Mr Burke's house 21 o'clock 16th Jany. 1891
118 volts at center of distribution. 116 lowest.

Determination of Obach + Standard Galvanometer Constants
21st Jan. 91.

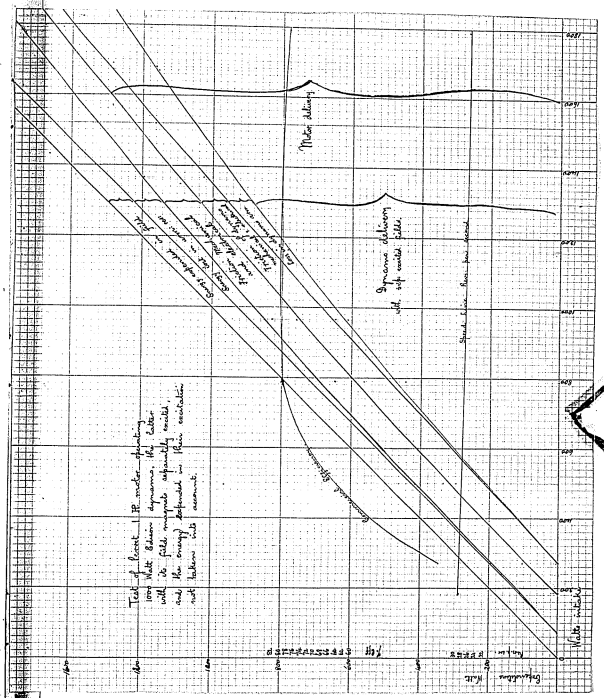
Copper electrolytic cell. same plates as above. Cautery battery. same solution.

	Weight of plates before test	Weight of plates after test	Gain	Loss	Accepted Transfer	Time of test Seconds	Mean Tangent	Accepted mean current	Tan per amp	Amp for Tan 1.	H
A	38.3995	42.1758	3.7743		3.7743	12,120	0.182	0.9482 amp	0.1919	5.211	
B	38.8242	35.0181		3.8061							
							~~0.223~~ g		1.290	0.7752	0.192



G = S = 187.200 g. l = 18

No. of Obs.	P.D. on Armature terminals	Shunt Deflection	Current absorbed by motor armature	Current in field winding	Energy in field	Current in armature	Energy in armature	D. drop in armature	E.M.F. generated by motor	Energy developed in armat.	Shunt R.P.m.	Shunt C.p.s.
1	0 volts	nils	0.108	0.568	0.92	0	0	0	—	—	—	—
2	112.0	121.75	0.256	1.505	.	.	2.937	114.1	0.77	121.0	183.4	1735	28.92
3	2[illegible]	.	0.365	1.937	.	.	1.369	164.7	1.13	120.6	165.1	1720	28.67
4	2[illegible]	.	0.422	2.221	.	.	1.653	201.3	1.36	120.4	199.0	1700	28.33
5	4[illegible]	121.0	0.780	4.105	0.564	68.2	3.537	427.9	2.92	118.1	417.8	1695	28.25
6	[illegible]	120.	1.170	6.158	0.560	67.2	5.590	670.8	4.61	115.4	645.1	1695	28.25
7	9[illegible]	120.	1.525	8.026	0.560	67.2	7.458	895.0	6.15	113.8	688.8	1688	28.13
8	11[illegible]	119.5	1.85	9.736	0.558	66.7	9.168	1096.0	7.56	112.0	1027.0	1660	27.67
9	13[illegible]	119.0	2.175	11.45	0.555	66.1	10.882	1295.0	8.98	110.0	1197.0	1650	27.5
10	15[illegible]	119.0	2.425	12.76	0.555	66.1	12.192	1451.0	10.06	108.9	1328.0	1620	27.0
11	15[illegible]	118.8	2.675	14.08	0.554	66.	13.512	1605.0	11.15	107.6	1454.0	1605	26.75
12	16[illegible]	118.7	2.700	14.21	0.554	65.8	13.642	1620.0	11.25	107.4	1465.0	1605	26.75
13	17[illegible]	119.4	2.900	15.26	0.557	66.5	14.692	1754.	12.12	107.3	1576.0	1600	26.67
14	17[illegible]	118.3	2.875	15.13	0.552	65.3	14.562	1723.	12.22	106.1	1576.0	1575	26.25



Test of a Perret 1 H.P. Motor, Labelled #1095
type C, C.C. 110 volts 1.8 amperes, revs. p.m. about 1800. Running
with hundred facing commutator, sept 8th 1890, W.N. Dickinson Jr.

This motor weighs on its base with pulley attached 192 lbs. Its bed plate weighs 32 lbs. It was mounted in the large tank with its axis 46.7 from the tank floor. The tank was immersed to a depth of 13.44 cms, so that it displaced 187200 c.c.

The resistance of the armature (hot) = 0.825 ω.
" " field (hot) = 215 ω

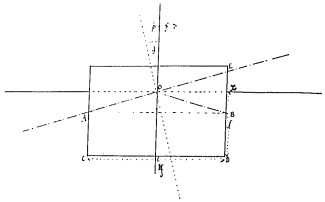
The motor was coupled with a 1000-Watt Edison dynamo, separately excited, whose armature had a res. (hot) = 1.01 ω.

Volts	Reading	Moment ounces	Volts Generated per cent per cent	6165 Moment	Energy delivered	Friction Watts	Mech. Efficiency	Electrical Efficiency	Volts at Dynamo terminals	Ratio: Eff. of Dynamo / Eff. of Motor	Current amperes	Energy Watts	Ratio Eff.
–	–								–	–			–
–	–		4.185			113.4	.06	0.62	–	–			–
120	16	4000	4.207	2466x10⁷	70.7 / 92	94.4	0.30 / 0.34	0.70	–	–			–
120	23.5	5875	4.25	3.622	102.6 / 95	96.4	0.379 / 0.38	0.726	–	–			–
120 / 120	33.6 / 10	19,400	4.18	11.96	338.0 / 319	78.8	0.680 / 0.64	0.8141	126.2 / 125.5	0.233093	1.733	207.3 / 214.1	4
120 / 120	29 / 25	32,250	4.085	19.89	562.1 / 590	83.0	0.761 / 0.798	0.873	118.8 / 118.5	0.48324	3.574	396.0 / 421.3	8
120 / 120	34.7 / 30	43,700	4.046	26.95	758.0 / 790	80.8	0.787 / 0.818	0.882	117 / 116.8	0.70673	5.236	612.6 / 640.6	12
120 / 120	42.5 / 30	54,300	4.048	33.48	926.2 / 922	109.8	0.746 / 0.793	0.883	114.5 / 116.0	0.92439	6.850	784.4 / 854.4	16
120	60	60,000	4.00	37.0	1017 / 1090	190. ?	0.747 ? / 0.801	0.878	110 / 112.2	1.15037	8.521	937.5 / 955	20
120 / 120 / 120	3 / 50 / 60	70,750	4.033	43.62	1178 / 1262	150.	0.776 / 0.865	0.875	107 / 108.1	1.32704	9.830	1052 / 1161	24
120 / 120	40 / 66	80,000	4.023	49.33	1320 / 1300	134.	0.789 / 0.854	0.869	105 / 117.0	1.48256	10.98	1153 / 1285	28
"		80,000	4.016	49.33	1320 / 1300	145	0.783 / 0.795	0.868	105 / 117.0	1.48256	10.98	1153 / 1285	28
120 / 120 / 120	3 / 50 / 60	85,750	4.023	52.88	1410 / 1422	166	0.774 / 0.790	0.865	102 / 116.6	1.64792	12.21	1246 / 1423	32
120 / 120 / 120	3 / 50 / 64	81,250	3.966	50.10	1315 /	201.	0.750 / 0.735	0.847	101 / 114.8	1.60033	11.86.	1195 / 1361	32

The efficiency of this motor when supplying any power p (watts) and supplied with 120 volts is approximately expressed by the equation

$$y = \frac{p}{P} = \frac{0.825\,(P-65)^2 - 165}{P}$$

Particulars of this motor. 416 wire on armature 4 layers of 14 turns each and 26 sections. 26 commutator bars. 2. brushes = 0.081" ?
p 19 B.S. wire on the armature = 3.3 ω = 2.6 lbs.
Wire on field 0.034" cond. = 0.025" = p 22 B.S. = 24 lbs. in all 6 magnets
Field cores are composed of 90 plates. Length of armature 27.5 from commutator to end of winding. Diameter of commutator 7.65
Brush width 3.5. Diameter of armature over all 10.0
" " " shaft 1.95



Problem – A rectangular tank is l cms. long, b broad, and h high. Its axis of flotation is vertical, and perpendicular to the base. It immerses to a depth of d cms. Its center of inertia is situated on the axis at a height c from the base, and a force whose moment is f acts round a horizontal axis perpendicular to the side l and passing through the axis of flotation at a point p on the axis of flotation distant s from the base. Determine the limiting angle θ of deviation.

The mass ~~AOB~~ADC is $bl\,(d - \frac{l}{2}\tan\theta)$. Its center of inertia is distant $\frac{1}{2}(d - \frac{l}{2}\tan\theta)$ from H along the axis OH, or $d - (\frac{d}{2} - \frac{l}{4}\tan\theta)$ from p.

The mass AOB is $\frac{bl}{2}(\frac{l}{2}\tan\theta)$. Its c.i. is distant $d - \frac{2}{3}(\frac{l}{2}\tan\theta)$ from H along the axis, or $d - (d - \frac{l}{3}\tan\theta)$ from p.

The mass BOE is $\frac{bl}{2}(\frac{l}{2}\tan\theta)$. Its c.i. is distant $\frac{2}{3}\times\frac{l}{2}$ from O

The compound mass ~~has~~ of AOEDC, has its x abscissa of c.i.

$$\frac{\frac{l}{3}\times\frac{bl^2}{4}\tan\theta}{bld} = \frac{l^2}{12d}\tan\theta = x$$

Its ordinate $-y$ is

$$\frac{bl\,(d - \frac{l}{2}\tan\theta)(\frac{l}{4}\tan\theta + \frac{d}{2}) + \frac{bl}{2}(\frac{l}{3}\tan\theta)\frac{l}{4}\tan\theta}{bld}$$

$$-y = (1 - \frac{l}{2d}\tan\theta)(\frac{l}{4}\tan\theta + \frac{d}{2}) + \frac{l^2\tan^2\theta}{24d}$$

Now resolving moments about the ~~point~~ line through p.

the force f $= -f$

- mass bld $= +bldg\,(s-c)\sin\theta$
- buoyancy $bldg$ $= +bldg\{(x\cos\theta + y\sin\theta) + (s-d)\sin\theta\}$

$\therefore\ f = bldg\,\{(s-c)\sin\theta + x\cos\theta + y\sin\theta + (s-d)\sin\theta\}$

$\frac{f}{bldg} = \sin\theta\,(c-d) + x\cos\theta + y\sin\theta$

$\frac{f}{bldg} = \sin\theta\,(c-d-y) + x\cos\theta$

for θ to be a maximum under given conditions $c = d+y$

or in other words the center of inertia of the tank should coincide with the center of buoyancy of the displaced water. This represents a condition of neutral equilibrium, and of instability for the tank. The rule is therefore to load the tank as lightly as possible, but having a given load to bring its center of inertia nearly up to the metacenter

Table for ~~Platinoid~~ Copper Wire @ 20°C. from data of Opposite page. B.W.G.

BWG.	B+S.	Diameter	Circular Mil	Weight: Lbs per foot	Weight: Lbs per ohm 20°C	Length: Feet per lb.	Length: Feet per ohm	Resistance: Ohms per lb.	Resistance: Ohms per ft.
1	0000	0.460	211,600	0.6412	13,120	1.5596	20.495	0.00007640	0.00004879
0000		0.454	206,116	0.6246	12,470	1.6010	19,970	0.00008019	0.00005008
000		0.425	180,625	0.5472	9,572	1.8272	17,500	0.0001045	0.00005714
~~000~~	000	0.4096	167,772	0.5084	8,260	1.967	16,250	0.0001211	0.00006154
00		0.380	144,400	0.4376	6,119	2.285	13,990	0.0001634	0.00007148
0		0.3409	115,600	0.3503	3,920	2.855	11,200	0.0002551	0.00008929
~~0~~	0	0.3249	105,560	0.3199	3,268	3.126	10,230	0.0003060	0.00009775
1		0.3000	90,000	0.2727	2,377	3.667	8,718	0.0004207	0.0001147
~~1~~	1	0.2893	83,694	0.2536	2,055	3.943	8,106	0.0004866	0.0001234
2		0.284	80,656	0.2444	1,909	4.092	7,812	0.0005238	0.0001280
3		0.259	67,081	0.2033	1,321	4.919	6,497	0.0007570	0.0001539
~~2~~	2	0.2576	66,358	0.2011	1,292	4.973	6,428	0.0007740	0.0001556
4		0.238	56,644	0.1717	941.2	5.824	5,487	0.001062	0.0001822
	3	0.2294	52,624	0.1595	812.6	6.270	5,098	0.001231	0.0001962
5		0.22	48,400	0.1467	687.5	6.817	4,688	0.001455	0.0002133
	4	0.2043	41,738	0.1265	511.2	7.905	4.043	0.001956	0.0002473
6		0.203	41,209	0.1249	498.2	8.006	3,992	0.002007	0.0002505
	5	0.1819	33,088	0.1003	321.3	9.970	3,205	0.003112	0.0003120
7		0.18	32,400	0.09818	308.1	10.185	3,138	0.003246	0.0003187
8		0.165	27,225	0.08250	217.5	12.12	2,637	0.004598	0.0003792
	6	0.162	26,244	0.07952	202.1	12.57	2,542	0.004948	0.0003934
9		0.148	21,904	0.06638	140.8	15.06	2,122	0.007102	0.0004713
10	7	0.1443	20,822	0.06310	127.2	15.85	2,017	0.007862	0.0004958
		0.134	17,956	0.05441	94.62	18.38	1.739	0.01057	0.0005750
	8	0.1285	16,512	0.05004	79.99	19.98	1.600	0.01250	0.0006250
11		0.12	14.400	0.04364	60.86	22.91	1.395	0.01643	0.0007168
	9	0.1144	13,087	0.03966	50.27	25.21	1,268	0.01989	0.0007886
12		0.109	11,881	0.03600	41.46	27.78	1.151	0.02415	0.0008688
	10	0.1019	10,384	0.03147	31.63	31.78	1.006	0.03162	0.0009940
13		0.095	9.025	0.02735	23.90	36.56	874.2	0.04184	0.001144
	11	0.0907	8,226	0.02493	19.86	40.11	797.0	0.05035	0.001255
14		0.083	6,889	0.02088	13.93	47.89	667.4	0.07179	0.001498
	12	0.0808	6,529	0.01979	12.51	50.53	632.5	0.07994	0.001581
15	13	0.072	5,184	0.01571	7.885	63.65	502.2	0.1268	0.001991
16		0.065	4,225	0.01280	5.237	78.13	409.2	0.1909	0.002444
	14	0.0641	4,109	0.01245	4.953	80.32	398.0	0.2019	0.002513
17		0.058	3,364	0.01020	3.322	98.04	325.9	0.3009	0.003068
	15	0.0571	3,260	0.009878	3.119	101.2	315.8	0.3206	0.003167
	16	0.0508	2,581	0.007822	1.955	127.8	250.0	0.5115	0.00400
18		0.049	2,401	0.007276	1.692	137.4	232.6	0.5910	0.004299
	17	0.0453	2,052	0.006218	1.236	160.8	198.8	0.8091	0.005030
19		0.042	1,764	0.005345	0.9132	187.1	170.9	1.095	0.005851
	18	0.0403	1,624	0.004921	0.7738	203.2	157.3	1.292	0.006357
	19	0.0359	1,289	0.003906	0.4877	256.0	124.9	2.050	0.008006
20		0.035	1,225	0.003712	0.4404	269.4	118.7	2.271	0.008425
21	20	0.032	1,024	0.003103	0.3078	322.3	99.18	3.249	0.01008
	21	0.0285	812.3	0.002462	0.1936	406.2	78.68	5.165	0.01271
22		0.028	784.0	0.002376	0.1804	420.9	75.94	5.543	0.01317
	22	0.0253	640.1	0.001940	0.1202	515.5	62.00	8.319	0.01613
23		0.025	625	0.001894	0.1146	529.0	60.54	8.726	0.01652
	23	0.0226	510.8	0.001548	0.07656	646.0	49.47	13.06	0.02021
24		0.022	484	0.001467	0.06875	681.7	46.88	14.54	0.02133
	24	0.0201	404	0.001224	0.04789	817.0	39.13	20.88	0.02556
25		0.020	400	0.001212	0.04695	825.1	38.75	21.30	0.02581
26		0.018	324	0.0009818	0.03082	1019	31.38	32.45	0.03187
	25	0.0179	320.4	0.0009709	0.03013	1030	31.04	33.19	0.03222
27		0.016	256	0.0007758	0.01923	1289	24.80	52.00	0.04032
	26	0.0159	252.8	0.0007661	0.01876	1303	24.49	53.30	0.04083
	27	0.0142	201.6	0.0006110	0.01193	1637	19.53	83.82	0.05120
28		0.014	196	0.0005939	0.01128	1684	18.98	88.65	0.05269
29		0.013	169	0.0005122	0.008381	1952	16.37	119.3	0.06109
	28	0.0126	158.8	0.0004812	0.007400	2078	15.38	135.1	0.06502
30		0.012	144	0.0004364	0.006086	2291	13.95	164.3	0.07168
	29	0.0113	127.7	0.0003870	0.004786	2584	12.37	208.9	0.08084
31	30	0.010	100	0.0003030	0.002934	3300	9.686	340.8	0.1032
32		0.009	81	0.0002455	0.001925	4073	7.846	519.5	0.1275
	31	0.0089	79.2	0.0002400	0.001841	4167	7.672	543.2	0.1303
33	32	0.008	64	0.0001940	0.001202	5155	6.199	831.9	0.1613
	33	0.0071	50.41	0.0001528	0.0007456	6544	4.883	1341	0.2048
34		0.007	49	0.0001485	0.0007046	6734	4.737	1419	0.2111
	34	0.0063	39.69	0.0001203	0.0004621	8313	3.845	2164	0.2601
	35	0.0056	31.36	0.0000950	0.0002886	10530	3.038	3465	0.3292
35	36	0.005	25.	0.00007576	0.0001834	13200	2.422	5453	0.4129
	37	0.00445	19.8	0.0000600	0.0001150	16670	1.918	8696	0.5214
36	38	0.004	16	0.00004848	0.00007512	20.630	1.550	13310	0.6452
	39	0.0035	12.25	0.00003712	0.00004505	26,940	1.186	22,200	0.8432
	40	0.0031	9.61	0.00002912	0.00002710	34,340	0.9308	36,900	1.074
00		0.3648	133,079	0.4033	5193	2.480	12,890	0.0001926	0.00007758
				303036d²	293445d⁴		9686.0d²		

Copper wire @ 60°C. — Platinoid wire @20°C

Copper: Length, Lbs per Ohm	Copper: Feet per Ohm	Copper: Resistance, Ohms per lb.	Copper: Ohms per ft	Platinoid: Weight, Lbs. per foot	Platinoid: Lbs. per ohm	Platinoid: Length, Feet per lb	Platinoid: Feet per ohm	Platinoid: Resistance, Ohms per lb	Platinoid: Ohms per ft	Diameter
11,980	17,920	0.00008705	0.00005581	0.6325	551.2	1.581	871.8	0.001814	0.001147	0.460
10,900	17,460	0.00009173	0.00005728	0.6161	523.2	1.623	848.9	0.001911	0.001178	0.454
8,368	15,300	0.0001195	0.00006536	0.5398	401.6	1.853	744	0.002490	0.001344	0.425
7,220	14,200	0.0001385	0.00007040	0.5015	346.5	1.994	691.1	0.002886	0.001447	0.4096
5,350	12,230	0.0001869	0.00008176	0.4316	256.7	2.317	594.9	0.003896	0.001681	0.380
3,427	9,794	0.0002918	0.0001021	0.3455	164.5	2.894	476.2	0.006079	0.002100	0.340
2,857	8,945	0.0003500	0.0001118	0.3155	137.1	3.170	435.0	0.007294	0.002299	0.3249
2,078	7,622	0.0004812	0.0001312	0.2690	99.72	3.717	370.8	0.01003	0.002697	0.3000
1,797	7,087	0.0005566	0.0001411	0.2502	86.20	3.997	344.7	0.01160	0.002901	0.2893
1,669	6,831	0.0005991	0.0001464	0.2411	80.09	4.148	332.2	0.01249	0.003010	0.284
1,155	5,679	0.0008659	0.0001761	0.2006	55.42	4.985	276.3	0.01804	0.003619	0.259
1,129	5,618	0.0008854	0.0001780	0.1983	54.20	5.043	273.3	0.01845	0.003659	0.2576
823.1	4,798	0.001215	0.0002084	0.1694	39.49	5.903	233.4	0.02532	0.004284	0.238
710.2	4,456	0.001408	0.0002244	0.1573	34.09	6.357	216.8	0.02933	0.004613	0.2294
610.0	4,098	0.001664	0.0002440	0.1447	28.85	6.911	199.4	0.03466	0.005016	0.22
447.0	3,536	0.002237	0.0002828	0.1248	21.45	8.013	172.0	0.04662	0.005815	0.2043
435.5	3,490	0.002296	0.0002865	0.1232	20.9	8.117	169.8	0.04785	0.005890	0.203
281.0	2,802	0.003559	0.0003569	0.09892	13.48	10.11	136.3	0.07418	0.007336	0.1819
269.3	2,743	0.003713	0.0003645	0.09684	12.93	10.33	133.4	0.07734	0.007493	0.18
190.1	2,306	0.005260	0.0004337	0.08138	9.125	12.29	112.1	0.1096	0.008916	0.165
176.7	2,222	0.005660	0.0004500	0.07844	8.478	12.75	108.1	0.1180	0.009251	0.162
123.1	1,855	0.008124	0.0005391	0.06548	5.907	15.27	90.25	0.1693	0.01108	0.148
111.2	1,763	0.008992	0.0005671	0.06224	5.336	16.07	85.76	0.1874	0.01166	0.1443
82.71	1,521	0.01209	0.0006576	0.05367	3.970	18.63	73.96	0.2519	0.01352	0.134
69.93	1,399	0.01430	0.0007149	0.04936	3.356	20.26	68.03	0.2980	0.01470	0.1285
53.22	1,220	0.01879	0.0008198	0.04305	2.553	23.23	59.31	0.3917	0.01686	0.120
43.96	1,109	0.02275	0.0009020	0.03912	2.109	25.56	53.91	0.4742	0.02043 (?)	0.1144
36.21	1,006	0.02762	0.0009938	0.03551	1.737	28.16	48.95	0.5757	0.02337	0.109
27.65	879.5	0.03617	0.001137	0.03104	1.327	32.22	42.79	0.7538	0.02690	0.1019
20.89	763.9	0.04786	0.001309	0.02698	1.003	37.06	37.17	0.9970	0.02951	0.095
17.36	696.4	0.05759	0.001436	0.02459	.8332	40.67	33.89	1.200	0.03523	0.0907
12.18	583.8	0.08212	0.001713	0.02060	.5844	48.54	28.38	1.711	0.03718	0.083
10.94	553.1	0.09144	0.001808	0.01952	.5248	51.23	26.90	1.905	0.04682	0.0808
×10 68.92	439.2	0.1451	0.002277	0.01550	.3308	64.52	21.36	3.023	0.05747	0.072
45.79	357.8	0.2184	0.002795	0.01263	.2197	79.18	17.40	4.552	0.05909	0.065
43.31	347.8	0.2309	0.002875	0.01228	.2078	81.43	16.92	4.812	0.07214	0.0641
29.05	285.0	0.3442	0.003509	0.01006	.1394	99.40	13.86	7.174	0.07446	0.058
27.27	276.1	0.3667	0.003622	0.009744	.1308	102.60	13.43	7.645	0.09407	0.0571
17.09	218.6	0.5851	0.004575	0.007716	.08201	129.6	10.63	12.19	0.1011	0.0508
14.79	203.4	0.6760	0.004917	0.007177	.07908	139.3	9.891	12.65	0.1183	0.049
10.80	178.8	0.9256	0.005753	0.006134	.05185	163.0	8.453	19.29	0.1376	0.0453
7.981	149.4	1.253	0.006692	0.005273	.03931	189.6	7.267	26.10	0.1495	0.042
6.766	137.5	1.478	0.007272	0.004854	.03246	206.0	6.689	30.81	0.1883	0.0403
4.264	109.2	2.345	0.009158	0.003853	.02046	259.5	5.311	48.88	0.1981	0.0359
3.850	103.8	2.597	0.009638	0.003661	.01848	273.1	5.047	54.11	0.2370	0.035
2.691	86.73	3.716	0.01153	0.003061	.01291	326.7	4.219	77.46	0.2988	0.032
1.693	68.78	5.908	0.01454	0.002428	.008121	411.9	3.347	123.1	0.3097	0.0285
1.577	66.40	6.340	0.01506	0.002344	.007568	426.6	3.229	132.1	0.3793	0.028
1.051	54.20	9.516	0.01845	0.001913	.005043	522.7	2.636	198.3	0.	0.0253
1.002	52.91	9.982	0.01890	0.001868	.004808	535.3	2.575	208.0	0.3884	0.025
0.6693	43.23	14.94	0.02312	0.001527	.003212	654.9	2.104	311.3	0.4752	0.0226
0.6013	40.92	16.63	0.02440	0.001447	.002884	691.1	1.994	346.7	0.5016	0.022
0.4188	34.20	23.88	0.02924	0.001207	.002009	828.5	1.664	497.8	0.6010	0.0201
0.4105	33.88	24.36	0.02952	0.001195	.001970	836.8	1.648	507.6	0.6069	0.020
0.2694	27.43	37.12	0.03645	0.0009686	.001293	1032	1.334	773.4	0.7494	0.018
0.2634	27.14	37.96	0.03685	0.0009578	.001264	1044	1.320	791.1	0.7576	0.0179
0.1681	21.68	59.48	0.04612	0.0007653	.0008067	1303	1.055	1240	0.9481	0.016
0.1640	21.39	60.97	0.04670	0.0007558	.0007870	1323	1.042	1271	0.9601	0.0159
0.1043	17.08	95.88	0.05856	0.0006027	.0005005	1659	0.8306	1998	1.204	0.0142
0.09862	16.59	101.4	0.06027	0.0005859	.0004732	1707	0.8071	2113	1.239	0.014
0.07326	14.31	136.5	0.06988	0.0005053	.0003516	1979	0.6959	2844	1.437	0.013
0.06472	13.44	154.5	0.07438	0.0004746	.0003105	2107	0.6540	3221	1.529	0.0126
0.05297	12.20	188.9 (?)	0.08200	0.0004305	.0002553	2323	0.5931	3917	1.686	0.012
0.04186	10.81	238.9	0.09248	0.0003817	.0002008	2620	0.5260	4980	1.901	0.0113
0.02565	8.467	389.8	0.1181	0.0002989	0.0001231	3346	0.4120	8123	2.427	0.010
0.01683	6.859	594.2	0.1458	0.0002421	.00008076	4131	0.3336	12380	2.998	0.009
0.01610	6.707	621.3	0.1491	0.0002368	.00007723	4223	0.3264	12950	3.064	0.0089
0.01051	5.420	951.7	0.1845	0.0001914	.00005043	5225	0.2636	19830	3.793	0.008
0.006519	4.268	1534	0.2343	0.0001507	.00003128	6636	0.2076	31970	4.816	0.0071
0.006161	4.141	1623	0.2415	0.0001465	.00002956	6826	0.2015	33830	4.963	0.007
0.004040	3.361	2475	0.2975	0.0001187	.00001939	8425	0.1635	51570	6.116	0.0063
0.002523	2.655	3964	0.3766	0.00009371	.00001211	10670	0.1292	82,580	7.740	0.0056
0.001603	2.117	6237	0.4723	0.00007472	.000007693	13383	0.1030	130,000	9.710	0.005
0.001005	1.677	9948	0.5964	0.00005918	.000004825	16900	0.08157	207,300	12.260	0.00445
0.0006579	1.358	15220	0.7380	0.00004782	.000003152	20,910	0.06592	317,300	15.170	0.004
0.0003938	1.037	25,390	0.9646	0.00003662	.000001890	27,310	0.05043	529,200	19.83	0.0035
0.0002869	0.8127	42,210	1.229	0.00002872	.000001137	34,820	0.03969	849,500	25.26	0.0031
4,539.0	11,270	0.0002205 (?)	0.00008874	0.3978	217.9	2.514	547.9	0.004589	0.001825	0.3648
		1.144 Cu@20	1.144 Cu@20°C		04.195 × copp. @ 20°C.			23.5 × res. of copper wire @ 20°C		

Pure Copper @ 100°C				German Silver @ 20°C				
Length		Resistance		Length		Resistance		
Lbs per ohm	Feet per ohm	Ohms per lb.	Ohms per ft	Lbs. per ohm	Feet per ohm	Ohms per lb.	Ohms per ft.	Diameter mils
10,200	15,910	0.00009804	0.00006286	628.9	1005	0.001590	0.0009947	0.460
9.681	15,500	0.0001033	0.00006452	596.7	979.4	0.001676	0.001021	0.454
7429	13,580	0.0001346	0.00007362	457.9	858.4	0.002184	0.001165	0.425
6410	12,610	0.0001560	0.00007928	395.1	796.8	0.002531	0.001255	0.4096
4750	10,860	0.0002105	0.00009210	292.8	686.3	0.003415	0.001457	0.380
3042	8,688	0.0003287	0.0001151	187.6	549.1	0.005331	0.001821	0.340
2537	7,943	0.0003942	0.0001259	156.4	501.8	0.006395	0.001993	0.3249
1814.5	6,766	0.0005420	0.0001478	113.7	427.7	0.008792	0.002338	0.3000
1595	6,289	0.0006269	0.0001590	98.33	397.5	0.01017	0.002516	0.2893
1482	6,064	0.0006748	0.0001649	91.32	383.3	0.01095	0.002609	0.284
1025	5,043	0.0009754	0.0001983	63.21	318.7	0.01582	0.003138	0.259
1003	4,990	0.0009972	0.0002004	61.80	315.3	0.01618	0.003172	0.2576
731.0	4,261	0.001368	0.0002347	45.07	269.3	0.02219	0.003714	0.238
630.5	3,956	0.001586	0.0002528	38.87	250.0	0.02573	0.004000	0.2294
533.6	3,639	0.001874	0.0002748	32.88	230.0	0.03041	0.004348	0.22
396.8	3,139	0.002520	0.0003186	24.47	198.3	0.04087	0.005042	0.2043
386.7	3,099	0.002586	0.0003227	23.84	195.8	0.04194	0.005107	0.2030
249.4	2,488	0.004010	0.0004020	15.38	157.2	0.06503	0.006361	0.1819
239.1	2,435	0.004182	0.0004106	14.74	153.9	0.06783	0.006497	0.1800
168.8	2,047	0.005924	0.0004886	10.41	129.4	0.09609	0.007730	0.165
158.7	1,974	0.006375	0.0005067	9.671	124.7	0.1034	0.008020	0.162
109.3	1,647	0.009150	0.0006072	6.739	104.1	0.1484	0.009610	0.148
98.72	1,565	0.01013	0.0006388	6.086	98.91	0.1643	0.01011	0.1443
73.42	1,350	0.01362	0.0007408	4.527	85.32	0.2209	0.01172	0.134
62.07	1,242	0.01611	0.0008052	3.827	78.49	0.2613	0.01274	0.1285
47.24	1,083	0.02117	0.0009234	2.912	68.40	0.3434	0.01462	0.12
39.02	984.3	0.02563	0.001016	2.406	62.19	0.4157	0.01608	0.1144
32.14	893.7	0.03111	0.001119	1.981	56.47	0.5047	0.01771	0.109
24.55	780.6	0.04074	0.001281	1.513	49.36	0.6608	0.02026	0.1019
18.55	678.4	0.05391	0.001474	1.144	42.88	0.8744	0.02332	0.095
15.41	618.4	0.06487	0.001617	0.9506	39.08	1.052	0.02559	0.0907
10.81	518.1	0.09250	0.001930	0.6667	32.74	1.500	0.03054	0.083
9.709	490.9	0.1030	0.002037	0.5984	31.03	1.671	0.03223	0.0808
6.120	389.9	0.1634	0.002565	0.3774	24.64	2.650	0.04059	0.072
4.065	317.7	0.2460	0.003148	0.2507	20.07	3.989	0.04983	0.065
3.845	308.8	0.2601	0.003238	0.2370	19.52	4.219	0.05123	0.0641
2.579	253.0	0.3878	0.003952	0.1590	15.99	6.288	0.06254	0.058
2.421	245.1	0.4130	0.004080	0.1493	15.49	6.700	0.06456	0.0571
1.517	194.1	0.6590	0.005153	0.09354	12.26	10.69	0.08154	0.0508
1.313	180.5	0.7614	0.005539	0.08097	11.53	12.35	0.08765	0.049
0.9588	154.3	1.043	0.006480	0.05914	9.747	16.91	0.1026	0.0453
0.7087	132.7	1.411	0.007538	0.04371	8.382	22.88	0.1193	0.042
0.6006	122.1	1.665	0.008189	0.03704	7.716	27.00	0.1296	0.0403
0.3786	96.99	2.641	0.01031	0.02334	6.127	42.84	0.1632	0.0359
0.3418	92.08	2.926	0.01086	0.02107	5.820	47.46	0.1718	0.035
0.2389	76.98	4.186	0.01299	0.01473	4.866	67.89	0.2055	0.032
0.1503	61.09	6.655	0.01637	0.009277	3.860	107.9	0.2591	0.0285
0.1400	58.93	7.142	0.01697	0.008636	3.724	115.8	0.2685	0.028
0.09325	48.12	10.72	0.02078	0.005754	3.041	173.8	0.3288	0.0253
0.08897	46.99	11.24	0.02128	0.005485	2.969	182.3	0.3368	0.025
0.05942	38.42	16.83	0.02603	0.003664	2.427	272.9	0.4120	0.0226
0.05339	36.39	18.73	0.02748	0.003291	2.300	303.9	0.4348	0.022
0.03716	30.37	26.91	0.03293	0.002292	1.919	436.3	0.5211	0.0201
0.03644	30.08	27.44	0.03325	0.002246	1.900	445.2	0.5262	0.020
0.02392	24.35	41.81	0.04106	0.001475	1.539	678.1	0.6497	0.018
0.02339	24.09	42.76	0.04151	0.001442	1.523	693.6	0.6568	0.0179
0.01493	19.25	67.00	0.05194	0.0009920	1.216	1087	0.8222	0.016
0.01456	19.01	68.66	0.05260	0.0008977	1.201	1114	0.8324	0.0159
0.009259	15.16	108.0	0.06596	0.0005708	0.9579	1752	1.044	0.0142
0.008757	14.73	114.2	0.06788	0.0005397	0.9311	1853	1.074	0.014
0.006506	12.69	153.7	0.07870	0.0004011	0.8032	2493	1.245	0.013
0.005744	11.94	174.1	0.08378	0.0003542	0.7541	2823	1.326	0.0126
0.004724	10.83	211.7	0.09234	0.0002913	0.6845	3433	1.461	0.012
0.003716	9.597	269.1	0.1042	0.0002290	0.6080	4366	1.648	0.0113
0.002278	7.519	439.0	0.1330	0.0001404	0.4753	7122	2.104	0.010
0.001494	6.086	669.3	0.1643	0.00009217	0.3848	10,850	2.599	0.009
0.001429	5.956	699.8	0.1679	0.00008811	0.3765	11,350	2.656	0.0089
0.0009328	4.812	1072	0.2078	0.00005754	0.3040	17,380	3.289	0.008
0.0005790	3.790	1727	0.2638	0.00003569	0.2395	28,020	4.175	0.0071
0.0005470	3.678	1828	0.2719	0.00003373	0.2323	29,650	4.304	0.007
0.0003587	2.984	2788	0.3351	0.00002211	0.1886	45,230	5.302	0.0063
0.0002240	2.357	4464	0.4242	0.00001381	0.1490	72,400	6.712	0.0056
0.0001423	1.880	7026	0.5320	0.000008772	0.1188	114,000	8.420	0.005
0.00008913	1.489	11210	0.6718	0.000005504	0.09407	181,700	10.63	0.00445
0.00005831	1.203	17,150	0.8314	0.000003596	0.07605	278,100	13.15	0.004
0.00003497	0.9208	28,600	1.086	0.000002156	0.05817	463,900	17.19	0.0035
0.00002103	0.7231	47,540	1.383	0.000001297	0.04566	771,000	21.90	0.0031
4031	10,004	0.0002481	0.00009996	248.4	632.1	0.0016025	0.001582	0.3648

Data for the compilation of wire tables.

Let ρ be the resistivity of the metal in ohms per c.c.
" d " " diameter " " wire in (inches thousandths) mils
" σ " " specific gravity of the material.

Then the res: per cm. $= \dfrac{\rho}{\frac{\pi(2.54)^2}{4}\left(\frac{d}{1000}\right)^2} = 197,355\,\dfrac{\rho}{d^2}$ | $\dfrac{\rho}{d^2}$

" " ohms per foot $= \dfrac{30.48\,\rho}{\frac{\pi(2.54)^2 d^2}{4\times10^6}} =$ ~~6,013,735~~ 6,012,440 $\dfrac{\rho}{d^2}$ | $\dfrac{\rho}{d^2}$

" " feet per ohm $= \dfrac{\pi(2.54)^2 d^2}{4\times 30.48\times10^6} = 1.6631\,\dfrac{d^2}{\rho}\times10^{-7}$ | $\dfrac{d^2}{\rho}$

" " weight gm per cm $= \dfrac{\pi}{4}\dfrac{(2.54)^2 d^2\sigma}{10^6} = 5.0671\times10^{-6}\,d^2\sigma$ | $d^2\sigma$

" " " lbs " " $= \dfrac{\pi}{4}\dfrac{(2.54)^2 d^2\sigma}{453.6\times10^6} = 1.1171\times10^{-8}\,d^2\sigma$ | $d^2\sigma$

" " " " foot $= \dfrac{\pi}{4}\dfrac{(2.54)^2 d^2\sigma\,30.48}{453.6\times10^6} = 3.4049\times10^{-7}\,d^2\sigma$ | $d^2\sigma$

" " feet per lb $= \dfrac{4\times453.6\times10^6}{\pi(2.54)^2 d^2\sigma\,30.48} = 2.937\times10^6\,\dfrac{1}{d^2\sigma}$ | $\dfrac{1}{d^2\sigma}$

" " ohms per lb $= \dfrac{4\times30.48\times10^6\rho\times4\times453.6\times10^6}{\pi\times(2.54)^2 d^2\times\pi(2.54)^2 d^2\sigma\times30.48} = 1.7666\times10^{13}\,\dfrac{\rho}{d^4\sigma}$ | $\dfrac{\rho}{d^4\sigma}$

" " lbs. per ohm $= \dfrac{\pi^2\times(2.54)^4 d^4\sigma}{16\times453.6\times\rho\times10^{12}} = 5.6606\times10^{-14}\,\dfrac{d^4\sigma}{\rho}$ | $\dfrac{d^4\sigma}{\rho}$

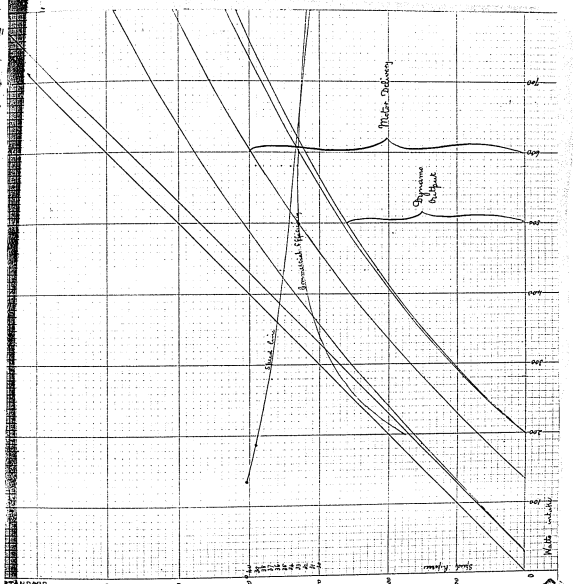
The values of these coefficients for different metals are as follows:—

Metal		ρ abs. units	ρ true ohms (106.3 cms)	$\frac{1}{\rho}$	σ	$\frac{1}{\sigma}$	$\frac{\rho}{\sigma}$	$\frac{\sigma}{\rho}$
Pure soft copper (Matth.)	0°	1593.5	1.5935×10^{-6}	6.2755×10^{5}	8.90	1.1173×10^{-1}	~~1.7804~~ $\times10^{-7}$ 1.7904	5.6159×10^{6} 5.585
" "	20°C	1717	1.717×10^{-6}	5.8241×10^{5}	-	-	~~1.9188~~ 1.9292	~~5.2127~~ 5.1840
" "	55°C 60°C 100°C	1934 1964 2212	1.934×10^{-6} 1.964 2.212	5.1706×10^{5}	-	-	~~2.1608~~ 2.1730	~~4.6280~~ 4.6019
Pure hard copper (Matth.)	0°	1630	1.630×10^{-6}	6.1350×10^{5}	8.90	-	~~1.8216~~ 1.8314	5.4914 5.460
" "	20°C	1757	1.757×10^{-6}	5.6195×10^{5}	-	-	~~1.9631~~ 1.9742	5.0940 5.0659
German silver	0°C	20,700 34,680 [illegible]	2.07×10^{-5} 3.468×10^{-5}	4.8309×10^{4} 2.8835×10^{4}	8.68	1.1152	2.3848×10^{-6} 3.996×10^{-6}	4.193×10^{5} 2.503
"	20°C	20,880 34,970	2.088×10^{-5} 3.50×10^{-5}	4.7893×10^{4} 2.8571×10^{4}	-	-	2.4055 4.032	4.5171 2.486
Platinoid	0°C	40,200	4.02×10^{-5}	2.4876×10^{4}	8.78	1.1390	4.5785	2.184
"	20°C	40,370	4.037×10^{-5}	2.4771×10^{4}	-	-	4.5979	2.175
Aluminium	0°C	2,881	2.881×10^{-6}	3.471×10^{5}	2.81	3.5587	1.0253×10^{-6}	0.9753×10^{6}
"	20°C	3,104	3.104×10^{-6}	3.2216×10^{5}	-	-	1.0690	0.93545

One circular mil foot of Matthiessen soft copper @ 0° = | @20° = 10.33 ω | @60° = 11.86 | @100° = 13.3 ω
" square [illegible] " " " " " | " = 8.112 | " = 9.276 | " = 10.45 ω

Commercial Iron	0°	12,000	1.2×10^{-5}	8.33×10^{4}	7.8	1.282×10^{-1}	1.539×10^{-6}	6.496×10^{5}
Approximate only, as great variation exists	20°	13,160	1.316×10^{-5}	7.6×10^{4}	7.8	1.282×10^{-1}	1.687×10^{-6}	5.928×10^{5}
	60°	15,460	1.546×10^{-5}	6.468×10^{4}	7.8	1.282×10^{-1}	1.982×10^{-6}	5.045×10^{5}
	100°	17,760	1.776×10^{-5}	5.631×10^{4}	7.8	1.282×10^{-1}	2.278×10^{-6}	4.390×10^{5}

No. of Obs.	P.D. at motor terminals	Shunt	Amperes	Energy in motor watts	Current in field amperes	Energy in field watts	Current in arm amperes	Energy in arm watts	Calculated drop in arm volts	E.M.F generated by arm	Energy in watts in arm	Speed R.p.m.	Speed of arm R.p.s.	E.M.F per pair
1	121.50	0.045	0.237	28.8	0.237	28.8	-					-		
2	-	0.209	1.10	133.6	-	-	0.863	104.8	3.32	119.2	102	2420	40.33	2.931
3	-	0.292	1.537	186.8	-	-	1.300	158.0	4.70	116.8	151.8	2350	39.17	2.98
4	-	0.310	1.632	198.3	-	-	1.395	169.5	5.06	116.3	162.3	2270	37.83	3.074
5	-	0.439	2.311	280.8	-	-	2.074	251.0	7.88	113.6	235.6	2215	36.92	3.077
6	121.	0.571	3.006	365.7	-	-	2.769	334.9	11.08	109.9	304.3	2185	36.42	3.015
7	-	0.690	3.58	435.2	-	-	3.313	404.4	14.40	107	357.7	2105	35.09	3.032
8	-	0.912	4.80	598.5	-	-	4.563	552.0	20.05	101.9	465.0	2045	34.09	2.981
9	-	1.270	6.682	868.8	-	-	6.447	780.0	29.66	91.3	588.7	1880	31.33	2.915
10														
11														



Test of C + C. ½ H.P. Motor 17th Jan. 91.

Marked type 3N ⊥ 976 110 volts - Ampere 2000 Revs per min.

The motor was mounted in the large tank, and coupled to the 1000-Watt Edison dynamo, which had resistance inserted in its field circuit in order to reduce the generated emf.

Emf. Pending	Moment	Moment x 6165	Defining Watts	Output - Watts (Pending)	Mech. Efficiency	Electrical efficiency	P.D. at dynamo terminals	Ampere Revs Target 1.039	Ampere	Field of Dynamo in amps	E.M.F. generated	Energy Absorbed Watts	
–													–
–		x10⁶		102									–
11 @ 5	12.50	7.700	30.19	120.6			100						–
11 @ 12	3.000	18.50	69.98	92.3			110						–
11 @ 26	6.500	40.05	148.0	87.6			108.	0.10894	0.939	0.8	105.9	96.3	a λ
250 @ 40	10,000	61.65	224.5	79.9			105	0.21256	1.565	1.5	106.5	165.7 144.3	2 λ
250 @ 52.5	13,125	80.92	284.0	73.7			101	0.31051	2.286	2.2	103.2	235.9 224.9	4 λ
250 @ 67.5	16,875	104.05	354.7	110.3			105	0.41763	3.074	3.0	108.2	333.6 322.3	6 λ
250 @ 50 500 @ 20	22,500	138.70	424.5	154.2			109.5	0.51983	3.827	3.8	113.3	433.6 419.	8 λ
													10 λ

This C + C. motor weighs 90 lbs. and occupies a cubical space of 20" × 11" × 15". The resistance of its armature between brushes is 3.5ω cold 4.6ω hot.

" " " field coils is 147ω cold + 515ω hot.

There are 27 bars in its commutator and diam. = 2.16". width of face 2⅞".

The armature is gramme type with 27 sections diam 4¼" over all. Bore of field 4⅞"

Determination of the specific gravity of some samples of Aluminium, German Silver and Platinoid. 19th Jan. 91.

Aluminium wire #1 coiled up	Weight in air	0.1055 g.		
	- Ag. Dest.	0.0675		
		0.0380	sp. g.	2.776
#2 - - - -	- air	0.1292		
	- Ag. dest.	0.0829		
		0.0463	sp. g	2.920

Since the danger is to make the sp. g. too small owing to adherent air bubbles the latter observation may be taken as having weight (2), and this makes the mean 2.812 = 2.809 at 4° T

German silver wire #1 coiled up	Weight in air	2.0093 g.		
	- Ag. Dest.	1.7779		
		0.2314	Sp g	8.684
- - - #2 - - -	in air	2.1361		
	- Ag. Dest.	1.8834		
		0.2457	- -	8.686
- - - #3 - - -	in air	2.0455		
	- Ag. Dest.	1.8106	- -	
		0.2349		8.706
This result corrected for temp = 8.682			Mean	8.692

Platinoid (Smith Mfg. Co.) Wire #1 coiled up	Weight in air	1.8492		
	- Ag. Dest.	1.3740		
		0.1752	Sp. g:	8.844
- #2 coiled up -	Weight in air	1.5029		
	- Ag. Dest	1.3317		
		0.1712	Sp. g:	8.778
Plate	Weight in air	2.6319		
	- Ag. Dest	2.3315		
		0.3004	Sp. g.	8.760
This result corrected for temp = 8.783			Mean	8.794

Temp. of the distilled water 18° C.

On the best size of platinoid wire to employ for connecting the 1/8th + 1/16th H.P. motor armatures to their commutators.

The res: of one coil of wire on the 400-Watt (1/8) armature is 0.8 ω (hot) and the res: of the platinoid connection about 0.6 ω or 0.75 of the coil res. This proportion is successful, with the much short-circuiting one coil or two coils, and until found deficient may be adopted. The res: of the armature will then rise in the proportion of $\frac{7}{4}$ to $\frac{7}{4} + 0.75$. For 1/32 ω. $\frac{1.75}{1.0}$ = 1.125 (4th extra)

The res: of one coil of the 1/16th H.P. motor is 1.6 ω hot

. . . . - platinoid connection should then be 1.2 ω

= 4.8 ω per foot = 0.0071" = 0.018 cm. diam.

In the 500-volt machine, the res: of one coil is 8.0 ω, and the resistance of one platinoid wire will be 0.75 ω. = 3.0 ω per foot = 0.009" = 0.0234 cm.

Constants of the Ring Tangent + Coarse-Wire Siemens Tan Galvanometer 22nd Jan. 91

No. of Ob.	Tan. of Sol. g.	Amperes	Tangent of Rise	Constant	Mean Constant.		Tangent of Siemens	Constant	Mean Constant	
1	1.5108	1.169	0.13165	0.1126			9.51436	8.1140		
2	1.8526	1.439	0.16286	0.1133	0.1137		11.430	7.950		
3	2.8229	2.190	0.25242	0.1152			19.081	8.71		

32	.000	66	.102
33	.003	67	.105
34	.006	68	.108
35	.009	69	.111
36	.012	70	.114
37	.015	71	.117
38	.018	72	.120
39	.021	73	.123
40	.024	74	.126
41	.027	75	.129
42	.030	76	.132
43	.033	77	.135
44	.036	78	.138
45	.039	79	.141
46	.042	80	.144
47	.045	81	.147
48	.048	82	.150
49	.051	83	.153
50	.054	84	.156
51	.057	85	.159
52	.060	86	.162
53	.063	87	.165
54	.066	88	.168
55	.069	89	.171
56	.072	90	.174
57	.075	91	.177
58	.078	92	.180
59	.081	93	.183
60	.084	94	.186
61	.087	95	.189
62	.090	96	.192
63	.093	97	.195
64	.096	98	.198
65	.099	99	.201

Meteorological Records

Date		Barometer Reading: Inches	Barometer Reading: Centimeters	Barometer Reading: Inches	Barometer Reading: Millimeters	Barometer Reading: Mean	Thermometer Reading: Min	Thermometer Reading: Deg.	Thermometer Reading: Hol.	Thermometer Reading: Degree Fahrenheit	Wind	Remarks
November 1890	28											
	29											
	30											
December	1st											
	2											
	3											
	4											
	5											
	6											
	7											
	8											
	9											
	10											
	11											
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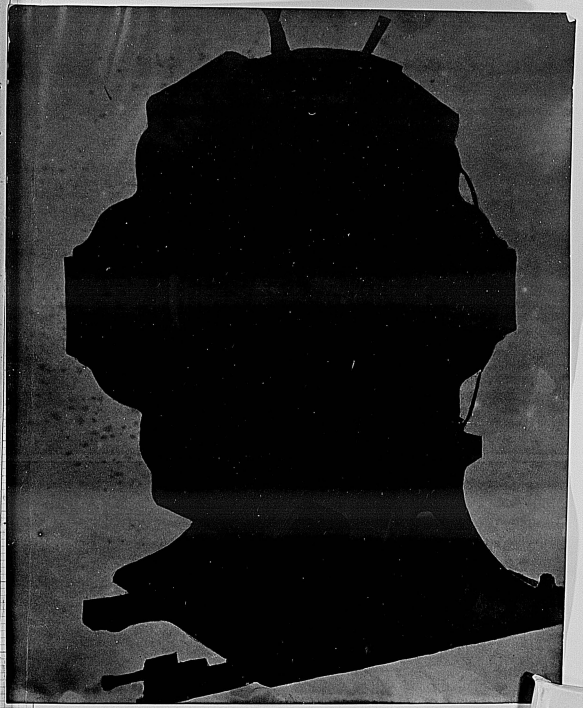
	28											
	29											
	30											
	31											
Jan 1891	1											



Saturation Curve
of 20 kilovolt Stahlpfeifer Spinning
Table Infinitely earthed
The current was accurate.
Behaviour of 20 kV
dynamo at this rate of exciting
Amperes after annealing dynamo circuit
Volts at terminals. (The usual allowance)

Abstract of a Report by Mr Kolben of the first tests on the new 20-kwt Edison multipolar machine just completed at Schenectady Works.

Blue-prints of the machine and its details are preserved for reference.

6 Poles. 125 volts. 160 amp. 1000 r.p.m. Weight 3070 lbs.

Armature. Body 175 lbs. # 24 B&S. oxydized iron wire.
Winding 204 divs 3 turns in each making 612 turns in all (gramme ring) in one layer. Triangular cross connections.

Field winding 68 lbs. of # 9 B&S on each core 408 lbs. in all. cores in series total resistance 8·16 ω. 8160 turns per core.

1st Test. Fields separately excited, and p.d. observed at armature terminals with no current supplied. Speed uniform @ 980 r.p.m. Results shown on curve sheet inserted.

2nd Test. The resistance in the field circuit was adjusted to give 125 volts at brushes with 200 amperes output on the main circuit. The load was then reduced and the EMF observed.

3rd Test. The drop in the field rec: box was observed with varying load, and constant EMF of 125 volts at terminals.

E.M.F. at MT v.	Current in main cct: amp.	Current in shunt ?	Drop in Field box v.	Speed r.p.m.	Remarks
125	0	9·75	45	1015	Steam low
"	75	11·5	32	980	and engine not
"	120	12·1	26	978	regulating well.
"	140	12·75	21	978	
"	160	13·25	16	950	
"	200	15	4	920	

4th Test. Heating.
After 11 hours run with 120 volts and 160 amp.
rise of temp. on field 19°C
" armat 27°C.
" 2¾ " " " 120 volts and 200 amp.
rise of temp. on field 25°C
" armat 40°C.

5th Sparking.
The machine ran perfectly sparkless with a load of 160 to 120 very slight sparking being noticeable at 200 and this was most probably due to the inaccurate division of the commutator. No moving of the brushes was necessary in reducing the load from 200 to 120 amperes, from 120 to 80, from 80 to no load, if the volts at m.t. were kept constant by the resistance of the field box. Brushes could be moved at no load and full field 1½" or 7 bars without producing sparking.

A note is added pointing out the large reluctance of the iron wire armature, and its prejudicial effects.

A telegram of the 20th Jan: announced that a cast iron backing ⅛" thick enveloping the armature had greatly improved the machine, saving the field energy from 1400 to 800 w.

Summary of Meteorological Observations at New York City during the Year 1820, as received in a letter addressed to Mr. Edison from L. N. Jesimofski Sergt: of Signal Corps.

Air pressure in inches. Mean reduced to 32° F		29.86
- - - 32° F and sea level		30.06
Highest reading - - - - - -	Jan. 1st	30.77
Lowest - - - - - - -	Oct. 23rd	29.35
Annual range		1.42
Mean monthly range		0.87

Mean hourly values

1 am	30.06	6 am	30.06	11 eve.	30.07	16 eve.	30.02	21	30.06
2	30.05	7	30.07	12 m	30.05	17	30.03	22	30.06
3	30.05	8	30.07	13	30.04	18	30.03	23	30.06
4	30.05	9	30.07	14	30.03	19	30.04	Mit.	30.06.
5	30.06	10	30.07	15	30.02	20	30.04		

Air temperature F. degrees

Mean 54°, Highest July 8th 95°, Lowest Mar. 7th 6°, Annual range 89°, greatest daily range, Feby. 7th 40°. Least daily range Sept. 11th 4°. Greatest monthly range March 65°. Least monthly range 8° (June). Mean of absolute monthly range 45°. Mean daily range 15°.

Mean hourly values

1 am	50°	7 eve.	49	13 eve.	56	19 eve.	55
2	50	8	50	14	57	20	54
3	50	9	51	15	57	21	53
4	49	10	52	16	56	22	53
5	49	11	54	17	56	23	52
6	49	12	55	18	56	24	51

Number of days Max: below 32° Jany. 2, Feby. 1, Mar. 4 Apr: 1 Dec. 7 Total number of days 15

Number of days min: below 32°. Jan: 15, Feby 11, Mar. 15, Apr. 3. Nov. 4 Dec. 23. Total 71

Number of days max: above 90° July 4 days

First ice formed Nov. 21st, last ice formed Apr. 1st

Humidity Mean dewpoint, degrees. 43° F. Mean relative humidity 73%.

Cloudiness Mean 0.54 greatest mean monthly Feby + Mar. 0.68 least mean monthly, June 0.51

There were 82 cloudless days, 150 partly cloudy, + 133 cloudy days.

Wind. Prevailing direction NW. Space integral 98,784 miles

Greatest monthly space integral Dec. 11,231, miles Least Sept. 6,534 miles

Highest velocity from NW. 55 miles per hour Jan. 22nd.

Number of times blowing from the N. (from 20 hrs. daily) 91, NE. 72, E. 22, SE. 90 S. 114, SW. 106, W. 91, NW 154, Calm 0.

Mean hourly values. (miles)

1 eve	11	7 eve.	10	13 eve.	13	19 eve.	12
2	10	8	10	14	13	20	11
3	10	9	11	15	13	21	11
4	10	10	12	16	13	22	11
5	10	11	13	17	12	23	10
6	10	Noon	13	18	12	24	11

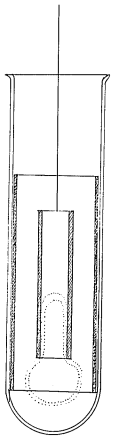
Precipitation (from Snow, rain hail, + sleet.)

Total: 52.3". Total depth of snowfall 45.6". distributed as follows— Jan: have Feby 4.0"; Mar. 21.3". Apr. 1.2". Nov. trace, Dec. 19.1". The last snow of season occurred Apr. 1st First snow Nov. 27th. Greatest monthly precipitation in Sept. 8.21". Least in Nov. 0.82". Greatest precipitation in any consecutive 24 hours Sept 16-17th 5.12". The average annual precipitation at N. Y. City (for the past 20 years) = 43.54". For each month Jany. 3.76" Feby. 3.69". Mar. 3.88" Apr. 3.27". May 3.05". June 3.26", July 4.36". Aug. 4.84", Sept 3.36", Oct. 3.36", Nov. 3.52", Dec. 3.21".

There have been 114 days on which 0.01" or more of rain or melted snow received. Thunderstorms occurred as follows— in Mar: 1, Apr. 3, May 5, June 9, July 3, Aug. 9, Sept. 5, Oct. 1.

The last frost of season occurred Apr. 1st. First " " " Oct. 3rd.

Full-size Cross Section of Meter Tube
showing zinc cylinder electrodes.



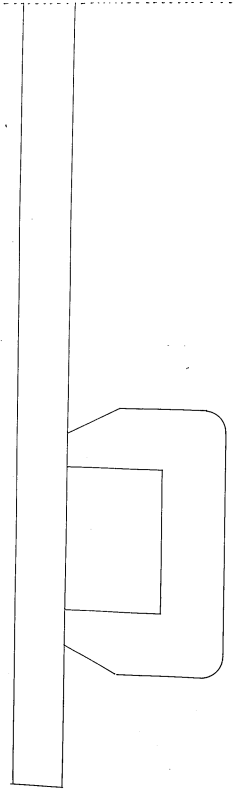
Tests of New Edison Electrolytic Meter. Jan. 22nd

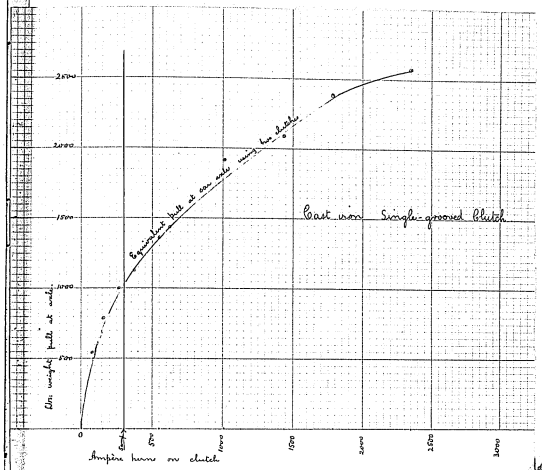
This instrument consist of a delicate clock spring (escapement spring) supporting a cylinder of zinc weighing 22 gms. immersed in a solution of $ZnSO_4$ 1.18. The position of the spring is shown by a pointer moving over a dial in a vertical plane. Before being finally set up the suspended zinc cylinder was bored out to a larger internal diameter, and a glass bulb with a hollowed end was inserted into this, as shown by the dotted lines. This bulb helped to float the cylinder, and reduces the load on the small spring. A film of kerosine oil was poured on the surface of the zinc sulphate solution. The suspending wire was of fine platinum, and rested on a little brass pulley about 0.5 diam. The recording dial was of german silver and graduated into a circle of degrees. The resistance of the cell and suspension was 30 ohms when first set up. The current was started at 16.50, 23rd. 5 mas and was interrupted for 3 hours on the following morning. The suspended cylinder was the anode. The needle indicated −1° at starting and +5° after 21 hours = 0.3° per hr.

21°	47	
24°	61	
39°	76	
56	133	
90	360°	Then reversed current.

Section of electromagnetic parts of actual clutch. Taken through the cross Axis

Full size





Data for the Calculation of Problems connected with the electro-deposition of Silver in $AgCn\,KCn$ Solution

The resistances of two experimental cells was observed to falls zero the measurements were comparatively rough, but may serve some practical purposes.

The dimensions of the cells were:— Right Cylinders.

Height 4·0 . Internal Rad: 2·0 . Ext: rad: 3·9.

Solution in	# 1	1 part $AgCn$	10 parts KCn	50 parts H_2O
. .	# 2	1 . .	10 . .	100 . .

Resistance of #1 0·3 ω Resistance of #2 0·35 ω

by bridge 1000/10 + 1000/100 . 4 Leclanché cells . Temp. 18°C.

If ρ be the resistivity of the liquid, R and r the radii, h the height, ∴ the resistance

$$dw = \frac{dr}{2\pi r}\frac{\rho}{h}$$

$$w = \frac{\rho}{2\pi h}\int_r^R \frac{dr}{r}$$

$$= \frac{\rho}{2\pi h}\log_e \frac{R}{r}$$

$$\rho = \frac{2\,w\,\pi h}{\log_e \frac{R}{r}} \quad \therefore \rho_1 = \frac{2 \times 0.3 \times 3.14 \times 4}{0.6678} = 11.29\ \omega \text{ per c.c.}$$

$$\rho_2 = \frac{2 \times 0.35 \times 3.14 \times 4}{0.6678} = 13.17\ \omega \text{ . .}$$

Test of electromagnetic clutch 24th Jan. 91.

The section of this clutch is represented on the opposite page. It was wound with 17½ lbs. of # 9 B.W.G in 60 turns (10 layers of 6) The follower clutch is of cast iron, and the face plate is also of cast iron. The measurement was made with slipping friction and not with starting friction. res: of clutch 0·125 ω cool.

No.	Clutch Depth	Radius	Pull observed lbs.	Moment Pot-lbs	Current amperes × 2	Ampere turns. × 2	M.M.F. × 2	Normal stress lbs per sq. in.	Stress per 10 cm.	Stress per 15 cm.	Pull at $\frac{R+r}{2}$	Pull P at $\frac{R+r}{2}$
1	2×0·089	12·5"	70	67·2	2·322	339·3	175	53·8	22·5	6·69	53·8	6300
2	2×0·240		103	98·9	5·22	313.	393	79·1	33·6	2·86	79·2	7680
3	2×0·34		130	124·8	8·57	532.	668	99·9	42·4	2·98	100·0	8630
4	2×0·48		147	141·1·2	12·52	751.	944	112·0	48·0	3·05	112·0	9195
5	2×0·71		177	170·0	18·52	1111.	1396	136·0	57·8	4·07	136·0	10,095
6	2×0·8		186	178·5	20·87	1252.	1574	143·0	60·7	4·27	143·0	10,340
7	2×1·27		248	238	33·65	2019.	2538	190·0	80·8	5·68	192·0	11,925
8	2×1·84		273	262	48·0	2880.	3620	210·0	89·0	6·26	209·6	12,500
9	2×2·275		310	297·6	59·35	3561.	4475	237·6	101.	7·60	238·0	13,320
10	2×3·00		335	322	78·26	4696.	5900	257·6	109.	8·67	257·6	13,890

The determination of total stress, and of P in this table are only estimates, since the acting coefficient is unknown, and the action is referred to the mean radius of the clutch.

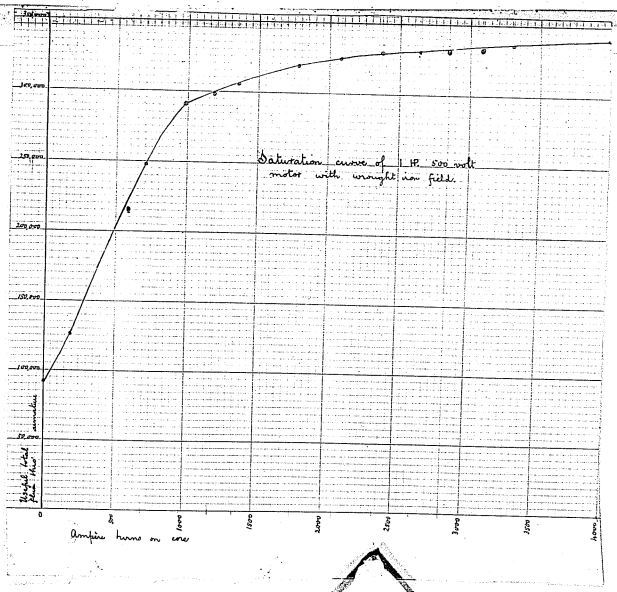
Effective area of piston dynamometer in Machine Shop.

The diam of the cylinder is $3\frac{9}{16}$" = 3·9375" = 12·18 sq. in.

. . . . piston rod is ¾" = 0·44 . .

Effective area 11·74 . .

A large angle plate weighing by scales 718 lbs, gave 0·94" with a #60 spring in the old style Labor indicator fitted to this piston, representing 56·4 lbs × 11·74 = 662 lbs or 92·2% of the true amount.


Saturation curve of 1 HP 500 volt motor with wrought iron field.
Magnetic field flux density
Ampere turns on core
0
500
1000
1500
2000
2500
3000
3500
4000

Test of 1 H.P. Edison Motor with wrought iron fields and 500-volt armature 24th Sang. 20. (II)

With 3 ampères in the field circuit and 500 volts on motor, the armature made about 2100 r.p.m.

The motor in wrought iron fields weighs 79 lbs. with 4" pulley.

- diameter of the core is 2.5" (6.35cm) wound to 3.95" (10) with #16 B.W.G. 0.065" cond: to 0.081". in 10 layers of 48 turns each. Mean diameter 3.25". mean circ. 10.21" = 0.85' × 480 turns = 408.4 = 0.997 ω. The actual res. is 1.065 ω slightly warm. The space occupied by this winding is 4.15 (7.325) = 30.48 c.in. The weight of wire is 5.23. so that the wt. per ft. of wire is in this instance 5.83 c.in. allowing for proper insulation on core say 5.75 #/in.

The following is a test of the magnetic circuit of the machine

	Ohms in field ckt.	Current in field ckt.	Amp. turns in field ckt.	MMF in field ckt.	Ohmic Tangent in armature	Ampère in armature	Drop in armature	EMF generated	Revolutions of armature per min.	Revolutions of armature per sec.	ϕ arm.	ϕ	ρ	~~Reluctance~~ Stator
	~~ohms~~						(1.5)							
1	1.714	5.958	4127	5187	0.330	0.256	5	117.5	407	6.78	343,700	17,185		3.418 × 10⁶
2	1.598	5.306	3987	5012	-	-	-	-	411	6.85	340,300	17,015		3.453 -
3	1.322	6.898	3312	4163	-	-	-	-	417	6.95	335,400	16,770		3.503 -
4	1.232	6.427	3085	3878	-	-	-	-	420	7.	333,300	16,660		3.522 -
5	1.138	5.937	2850	3582	-	-	-	-	422	7.03	331,600	16,580		3.543 -
6	1.052	5.488	2634	3311	-	-	-	-	424	7.07	329,700	16,485		3.564 -
7	0.947	4.941	2372	2982	-	-	-	-	426	7.1	328,300	16,415		3.579 -
8	0.827	4.315	2071	2603	-	-	-	-	431	7.18	324,700	16,235		3.619 -
9	0.712	3.715	1783	2241	-	-	-	-	438	7.3	319,300	15,965		3.679 -
10	0.545	2.844	1365	1716	-	-	-	-	458	7.63	305,500	15,275		3.846 -
11	0.474	2.473	1187	1492	-	-	-	-	470	7.83	298,400	14,920		3.947 -
12	0.395	2.061	989	1243	-	-	-	-	482	8.03	295,200	14,515	6.29 × 10⁻⁶	4.047 -
13	0.282	1.471	706	878	0.3395	0.263	5.1	117.4	563	9.4	248,000	14,400	.566 × 10⁻⁶	4.737 -
14	0.213	1.111	533	733	0.3594	0.275	5.4	117.1	670	11.16	216,500	10,825	5.92 × 10⁻⁶	5.425 -
15	0.077	0.402	193	243	0.4932	0.382	7.5	115.0	1083	18.05	126,400	6320	7.23 × 10⁻⁶	9.098 -
16	0.	0	0	0	1.1918	0.924	18.0	104.5	1341	22.35	93,800	4,640		11.26 -

Res. of armature between brushes cold (19.5°) 5040 wire in armature.

Operating the machine with 500 volts at mt. the current in the field being 4.801 7 or 230½ a.t. the current taken by the armature = 0.444 7 (tan⁻¹ 3°20' = 0.1311) and the speed 1725 revs. The drop in the armature being 5.7 volts, 491.3 in the e.m.f. generated. the emf per rev. per sec. = 17.09, that in the preceding test 16.09 with 122 volts.

Allowing 750 Ohms, and 0.2 amp = 1875 turns in all, to have a resistance of 4 ohms. 1875 × 0.85 = 1594' for ω = 400' per ω = 0.072 #15 B.W.G. 1600 × 0.01571 = 25 lbs. 1600' with 5.2 lbs = 307.6' per lb. #21 B.W.G. 1600 × 0.0715 = 19 in. Allowing 500 AT and 0.4 amp = 1250 turns = 1063' weighing 5.5 lbs = 193' per lb. = #19 B.W.G. = 5.5 × 1.25 = 6.88 c.in.

Tests of the Sprocket Belt on the Street Car Experimental Truck 26th Jan. 91.

This belt is made of links 1/8" thick & ⊗ shape. It weighs 13 lbs. per foot and is 6" wide 19' long. It runs over a sprocket 16" in pitch diameter, and over two pulleys on the axles 24" diameter. One of these pulleys was faced with sheet lead 1/16" thick the other with blocks of oak. The car was in these tests raised off the truck, and the motor started, it was then lowered down to put work on the axles, and the pulls from these horizontally was measured with a dynamometer.

No. of Obs.	Volts	Amperes	Watts	Speed motor	Speed of axles	Sag of belt	Driving pulley	Following pulley	Dynamo. pulls.	Weight	Length of tension on belt from to velocity	Pulls in lbs.
1	450	20	9000	240	35	—	Wooden	Leather	720 lbs	Tension motor	19'60"	1508
2	"	—	—	—	—	9/16"	"	" on back	780	- - -	19'60"	1508
3	"	—	—	"	"	5/8"	"	"	1200.	- - -	18'6"	1350
4	"	—	—	—	—	5/16"	Leather	Wooden back	900.	- - -	87'	1120
5	500	29	14,500	280	42	5/16"	—	- - -	1200	. . +720	87'	1120
6												

Constant of Ring Tangent Galvanometer after readjustment 27th Jan. 91

Obach 0.745 ± (3.5885) Ring 27.° 0' = tan" 0.50953 = 0.1311 tan per amp.

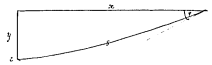
Calibration of Obach Galvanometer 27th January 1891.

This instrument was readjusted, and mounted with hole, slot and plane. It was then calibrated by copper electrolysis after

	Weights Before	of Plates After	Difference Gains	Loss. grms.	Accepted transfer grms.	Time of test seconds	Transfer per second grms.	Mean Current amperes (C.G.S.)	Number of Obach Reading	Mean Reading	Tans per 1 amp.
A	41.6565	42.2647	0.6082		0.6899	900	0.0007666	2.332	79	0.4472	0.1918
B	34.9693	34.2794		0.6899							

Test of the other Galvanometers

Instrument	Reading	Obach	amp.	Tans of Reading	Tan per amp.	Mean	H
Standard	47.°30'	0.164	0.8552	1.09131	1.276	1.278	0.194
"	47.°20'	0.163	0.850	1.08496	1.276		
"	59.°0	0.249	1.295	1.66143	1.282		
"	59.°20'	0.248	1.293	1.68643	1.304		
Ring	21.°30'	0.569	2.967	0.39391	0.1328	0.13275	
	26.°10	0.710	3.703	0.49134	0.1327		
Sinus cosine	72.°40'	0.083	0.4328	3.2146 Exp. root	0.7402	7.40	
Dynam. 4 ohm	20.°4'	2.455	12.80	116.293	1.116	1.1165	
	15.°5'	2.16	12.26	12.570	1.038		



$$y = \frac{x^2}{2c}\left[1 + \frac{1}{12}\left(\frac{x}{c}\right)^2\right]$$

$$x = \sqrt{2cy}\left(1 - \frac{y}{12c}\right)$$

$$c = \frac{x^2}{2y} + \frac{y}{6}$$

$$\tan\gamma = \frac{2y}{x}\left[1 + \frac{1}{3}\left(\frac{y}{x}\right)^2\right]$$

$$s = x\left[1 + \frac{1}{6}\left(\frac{x}{c}\right)^2\right]$$

Problem — Having given the dimensions of the car wheels and truck shown on p: 66, to determine what the catenary pressure will be on the two axles when 1600 lbs is delivered by each belt at the axle.

1st Assume that all the work is done by the leading wheel, lined with oak for which $\mu = 0.35$

In order to deliver a pull of p: lbs. weight at the axle, the difference of tensions must be αp where α is the ratio of the belt radius to the wheel radius.

$$\therefore p = \alpha(T_2 - T_1)$$

$$T_2 = \epsilon^{\mu\theta} T_1$$

$$\therefore p = \alpha T_1(\epsilon^{\mu\theta} - 1)$$

$$\text{or } T_1 = \frac{p}{\alpha(\epsilon^{\mu\theta} - 1)}$$

$$T_2 = \frac{\epsilon^{\mu\theta} p}{\alpha(\epsilon^{\mu\theta} - 1)}$$

$$T_1 + T_2 = \frac{p(\epsilon^{\mu\theta} + 1)}{\alpha(\epsilon^{\mu\theta} - 1)}$$

$T_1 + T_2$ is the pull brought to bear on the axle journal.

$$\alpha = 0.8 \qquad \theta = \pi \qquad \mu = 0.35 \qquad p = 1600$$

$$\therefore p = 0.8(T_2 - T_1)$$

$$1600 = 0.8\, T_1(\epsilon^{1.10} - 1)$$

$$T_1 = \frac{2000}{2.01} = 1000$$

$$T_1 + T_2 = \frac{2000(3.01 + 1)}{3.01 - 1}$$

$$= 2000 \times \frac{4}{2} = 4000 \text{ lbs. wt.}$$

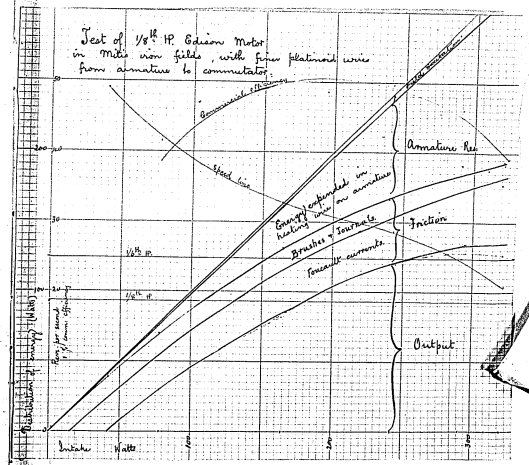
Abstract of a Report of the Pull required to start a car on level rails, by Mr John Kruesi, forwarded to the Engineer-in-Chief on the 29th January 1891

Conditions. Car placed on rails (4'8½"), a steel rope attached to the periphery of the wheel and a direct pull applied by means of weights. Diameter of wheel. 30". After each test the car was put back into the same position and the lap of the rope on the wheel kept the same, so that the tests were made under the same conditions and on the same part of the rails. The first test on the traction of the car empty gave a result of 235 lbs. pull, but after the wheels had passed over the rail two or three times, this was decreased to the above figure (216).

Weight of car body 3405 lbs.
" " truck 3910 "
" " motor 4240 " 11,555 lbs

No. of trial	Weight of car	Load added	Total weight lbs.	Pull required to move weight	Pull per ton of 2000 lbs	% of weight lbs		
1	11,555	–	11,555	216	37.4	1.87		
2	11,555	2078	13,633	240	37.2	1.76		
3	11,555	4121	15,676	260	33.2	1.66		
4	11,555	8286	19,841	300	30.2	1.51		

No. of Obs.	P.D. at motor terminals volts	Ohmic current in motor amperes	Res. of field ω	Res. of armature ω	Drop in field volts	Energy in motor watts	Energy in field watts	Energy in armature watts	Drop in armature volts	E.M.F. of armature volts	Energy developed in armature watts
1	12.0·5	0·0655	0·339	1·0	15·0	0·34	41·2	0·115	41·1	5·09	116·1	1·8
2	12·0	0·122	0·6365	1·0	16·0	0·64	77	0·41	76·6	10·7	109·7	6·9
3	12·0·5	0·260	1·357	1·1	16·5	1·5	163·5	2·04	161·5	22·4	96·6	30·4
4	115·5	0·392	2·045	1·1	16·75	2·25	242·3	4·6	237·7	341·25	82·0	60·0
5	117·9	0·473	2·468	1·2	17·0	2·9	291	7·2	283·8	42·0	77·0	93·8
6	117·5	0·525	2·739	1·35	17·9	3·7	322	10·1	312·9	49·0	62·8	134·4
7	116·5	0·510	2·661	1·35	17·9	3·6	310	9·6	300·4	47·6	68·9	117·1



Test of 100-Watt Edison Motor after setting it in mitis iron fields, and using smaller platinoid wire between armature and commutator, also using grease tubes. 29th Jan. 91.

The res: of armature between diameters — cool - 17.75Ω including platinoid
- - - - brushes — - - 14.95Ω -
- - - - - — hot - 16.

Inductance. - - - (in field unwinded) 394 h. res: 10.5 h. res: 0.95 cool 12.

- - field (armature in place)

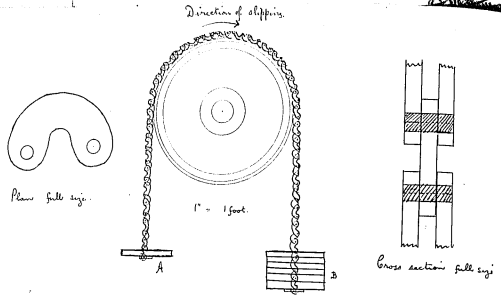
Motor floated and driving the 3/4 H.P. Mitis iron dynamo sep: excited.

Watts armature watts	Speed R.p.m.	R.p.m.	Scale Rdg gms	⊙ cms	Moment compm	Gives Moment	Delivery	Commut efficiency	Electrical efficiency	Effect of arm.	Friction	Conditions
			Motor Self exciting (Ashes commut)									
1.8	2460	49.0	50	⊙ 0.0	—	—	—	0	0	39.3	39.3	Running light
6.9	2490	41.5	50	⊙ 23.1	115.5	7.120×10^6	29.56	0.384		69.8	40.2	Driving arm: light
30.4	1975	32.9	50 500	⊙ 19.5 ⊙ 10	97.5	2.451×10^7	81.62	0.499		131.1	49.5	Opposing S. Exc.
60.0	1715	28.6	50 500	⊙ 36.2 ⊙ 10	68.10	4.199	120.1	0.496		167.7	47.6	1 lamp
93.9	1490	24.9	50 500	⊙ 44.4 ⊙ 15	87.20	5.376	133.3	0.458		190	56.7	2 - -
134.4	1240	20.7	50 500	⊙ 3.5 ⊙ 20	95.25	6.057	125.4	0.39		177.5	52.1	3 - -
117.1	1235	20.7	"	"		-	-	0.39		183.3	57.9	after 1 hour

The temp: of the field was 95° F after 2 hours run.

The maximum commercial efficiency of the motor, when tested on the 8th Jan: in the wrought iron fields was 0.38. The mechanical friction is probably the same but the electrical friction appears to have been materially reduced. The total friction is now from 40 to 55 Watts. On the 8th of January it was from 70 to 90 Watts.

The pole pieces are the same, and the armature is the same except that the platinoid wire has been reduced from 0.011" to 0.0073"



Measurement of some coefficients of friction

20th January 1831

An iron pulley, faced (to 24" diam) with the substance tested was fixed with its axis horizontal. A chain, (and in the case of rubber also a strip) of iron formed of 144 links, length 9¼". There are 94 links one to each 1st pitch. The links are of the dimensions shown on the opposite page. The weight of this length of chain was 10 lbs. and with a shoe at each end 13. In almost all the tests a fixed weight was supported at one end and weights added to the other end until slipping commenced or could be maintained. The angle of embrace was π.

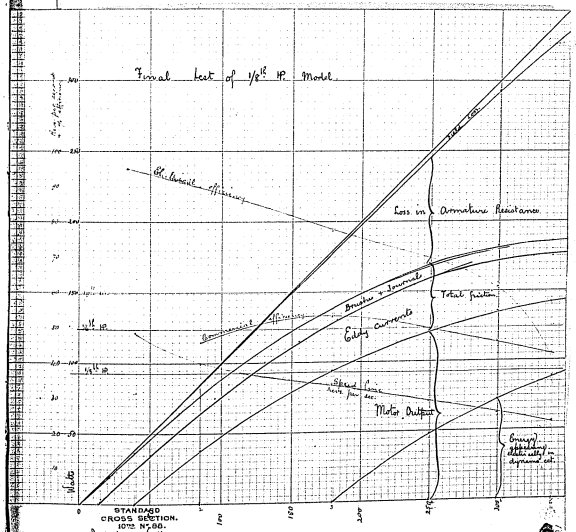
These results are tabulated allowing 3 lbs on each side for chain-weight and assuming no weight in the length of chain resting on the pulley.

No. of Obs.	Chain	Diam. of pulley	Material	Condition	Total Weight A lbs	Total Weight B lbs	ratio B/A	μθ	μ	remarks
1	Link	24¾"	½" leather face	normal	3.9 lbs	8.5.5	2.673	0.9821	0.31	sliding
2				wetted	"	5.8	1.813	0.5933	0.19	"
3				wet sand	"	12.0	3.938	1.3712	0.44	"
4				oiled	"	6.4	2.00	0.6931	0.22	"
5	Link	24¾"	Wooden	normal	"	6.4	2.00	0.6931	0.22	"
6	"			wetted	"	10.4	3.25	1.1787	0.38	starting
7	"			"	"	7.4	2.313			moving
8	"			wet sand	"	10.0	3.125	0.8372	0.27	starting more
9	"			oiled	"	6.4	2.0	1.1141	0.36	moving
10	"			"	"	12.3	3.845	0.6931	0.22	starting
11	"	25½"	½" rubber	normal	"	29.3	9.16	1.3461	0.43	"
12	steel band	"	"	"	7lbs.	53.5	7.644	2.1248	0.71	at 1 s moving
13	"	"	"	wetted	"	"	"	2.0334	0.65	"
14	"	"	"	oiled	8.25	26.5	3.212	2.0334	0.65	"
								1.1663	0.37	"

The wooden pulley had its face formed of oak blocks with the grain radial. The rubber pulley had its face coated with ½" thick continuous rubber not pure gum but lightly vulcanized. The steel band used in the last experiment was 0.007" thick and 1½" wide.

Material	on	Material	Starting μ	Moving μ	
Iron chain	"	lead dry	0.35	0.31	
	"	do. wet	0.25	0.19	
	"	do. wet sanded	0.50	0.44	
	"	do. oiled	0.25	0.22	
	"	oak across the grain	0.25	0.22	
	"	do. wet	0.38	0.27	
	"	" wet sanded	0.38	0.36	
	"	" oiled	0.43	0.22	
	"	rubber normal	0.71	0.71	
steel band	"	" "	0.65	0.65	
	"	" wetted	0.65	0.65	
	"	" oiled	0.37	0.37	

No. of Obs.	P.D. in water rheostat	Ohmic	Current flow water rheostat	Energy in water watts	Res. field Ω	Drop in field volts	Energy in field watts	p.d. in armat. volts	energy in armat. watts	res. of armat. Ω	drop in armat. volts	Energy lost in armat. watts	e.m.f. generated volts	Energy equivalent torque	Speed r.p.m.	r.p.s.
1	121.5	0.061	0.318	38.6	1.0	0.3	0.1	121.2	38.5	16.5	5.25	1.79	115.9	36.8	2900	48.37
2	"	0.132	0.639	83.7	"	0.7	0.5	122.8	83.2	16.75	11.5	7.9	109.3	75.3	2395	39.92
3	120	0.285	1.197	178.2	"	1.5	2.2	118.5	176.2	17.0	25.3	37.6	93.2	138.6	2025	33.75
4	120	0.396	2.066	248.0	"	2.1	4.3	117.9	243.7	17.5	36.2	74.8	81.7	168.9	1705	28.42
5	121.25	0.472	2.463	298.6	1.1	2.7	6.7	114.6	293.9	18.0	44.3	109.1	70.3	182.8	1510	25.18
6	121.75	0.534	2.786	339.2	1.2	3.3	9.3	112.5	329.9	18.5	51.5	143.5	61.0	186.4	1348	22.47
7	119.5	0.587	2.97	352.8	1.3	3.9	11.5	108.0	343.3	19.0	56.4	167.5	52.6	175.8	1218	20.3
8																



Test of the 1½ H.P. motor after changing the platinoid wire a second time in order to reduce sparking.

The only change in the motor since the test recorded on page 80 has been in the platinoid wire which have been reduced to a diameter of 0.0056" with a resistance of 1.140 each.

Motor self exciting, mounted in boat.

field no.	I.p.	Total lb. per ⊡ in.	Moment	Lb. Moment	Output watts	Elect. η	Mech. η	voltage per pair	field at pole tips	flux	Amperes in pair	drop in pair	EMF generated	Energy lb. feet per second	Motor fitting
0	(33)		-	-		0.953	0	3.66							
5	33.92	50 @ 31.2	1560	10¹ 0.918	38.4	0.90	0.489	2.74							36.8 Eight.
5	33.72	{500 @ 10 / 20 @ 7.1}	4,325	2.802	94.6	0.777	0.530	2.76							36.9 eight
5	31.63	{500 @ 15 / 20 @ 10}	7,000	4.316	122.7	0.681	0.495	2.88	113.25	0.05332	0.417	1.84	115.1	48	44.0 D.F. & Ex.
0	25.71	{500 @ 20 / 20 @ 14.7}	8,765	5.404	136.	0.612	0.456	2.79	100	0.09335	0.703	3.09	103.1	72.5	46.2 1 lamp.
8	22.62	{500 @ 20 / 20 @ 6}	10,300	6.351	142.7	0.621	0.421	2.72	90	0.12714	0.947	4.17	54.2	89.2	44.8 2 lamps
7	20.3	{500 @ 20 / 20 @ 22}	11,100	6.842	138.9	0.392	0.392	2.54	-	0.13461	1.014	4.46	-	-	43.7 3 lamps
															36.9 4 lamps

Particulars of the completed motor.

Weight without wooden base 19½ lb.
- with - 21 -
- of armature 4½ lb.

Diameter of core 1.4"
over wire 2.28" } Mean diam. ~~1.86~~ ~~1.92~~
- - wire 0.442"
- outside covering

Resistance of field winding 0.955Ω @ 15°C.
Length 222'
Weight 1.62 lb.
Turns. 480

Res. of armature between brushes (cold) 16.0Ω
17.75Ω hot

The inductance of the armature 394 H between brushes
- - - one coil on . . 9.2 - field off
- - - - - - - 6.7 - - on under pole
- - - - - - - 2.0 - - between poles

Res. of one coil of the armature 1.33Ω cold
1.5Ω hot

Length of platinoid wire 3½"
diameter - - - 0.0056"
res. - - - 1.14Ω

If the friction on the rubber were independent of the velocity the motion would be accelerated. It is not accelerated, therefore the friction is a function of the velocity, and the equation of motion is of the form $m\frac{dv}{dt} = f - \varphi(v)$

The form of the function $\varphi(v)$ is not known, but the results observed are capable of being represented (to a first approximation) by one of two hypotheses 1st that $\varphi(v) = \alpha v$

2nd " $\varphi(v) = \beta(v^2)$

Consider the 1st hypothesis

$$m\frac{dv}{dt} = f - \alpha v \qquad \text{Let } f = \alpha(V)$$

$$\text{Then } m\frac{dv}{dt} = \alpha(V - v)$$

$$\text{or } dt = \frac{m}{\alpha}\left(\frac{dv}{V-v}\right)$$

$$t = -\frac{m}{\alpha}\log_e\left(\frac{V-v}{V}\right)$$

$$\frac{V-v}{V} = e^{-\frac{\alpha t}{m}}$$

$$v = V\left(1 - e^{-\frac{\alpha t}{m}}\right)$$

$$= \frac{f}{\alpha}\left(1 - e^{-\frac{\alpha t}{m}}\right)$$

On the 2nd hypothesis $m\frac{dv}{dt} = f - \beta v^2 \qquad \text{Let } f = \beta V^2$

$$\text{Then } m\frac{dv}{dt} = \beta(V^2 - v^2)$$

$$dt = \frac{m}{\beta}\frac{dv}{2V}\left(\frac{1}{V+v} + \frac{1}{V-v}\right)$$

$$t = \frac{m}{2\beta V}\log_e\left(\frac{V+v}{V-v}\right)$$

$$\frac{V+v}{V-v} = e^{\frac{2\beta V t}{m}}$$

$$v = V\frac{e^{\frac{2\beta V t}{m}} - e^{-\frac{2\beta V t}{m}}}{e^{\frac{2\beta V t}{m}} + e^{-\frac{2\beta V t}{m}}} = V\tanh.\frac{2\beta V t}{m}$$

$$= \sqrt{\frac{f}{\beta}}\tanh.\frac{2\beta V t}{m}$$

On the first hypothesis, the time required to generate ~~the~~ half the limiting velocity is $t_{\frac{1}{2}} = -\frac{m}{\alpha}\log_e 0{\cdot}5 = 0{\cdot}694\frac{m}{\alpha}$

On the second hypothesis $t_{\frac{1}{2}} = \frac{m}{2\beta V}\log_e 3 = \frac{1{\cdot}099}{2}\frac{m}{\beta V} = 0{\cdot}55\frac{m}{\beta V}$

Such acceleration as exists is apparently practically over in one second so that 0·5 sec is max limit of $t_{\frac{1}{2}}$ so that on either hypothesis α or β have large magnitude.

Experiments on the frictional resistance of vulcanised rubber to motion over its surface. 31st Jan. 91.

The rubber band pulley 200 cms in circumference alluded to on page 81 was again used for this experiment. It was clamped to its axle which was horizontal. The steel band of length 183 breadth 4·15 and 0·01 thickness 0·01 (cms) weighing 54 gms already described on p. 81 was laid over the pulley at right angles to the axis, and a wire weighing 443·4 gms (11×2·7 + 50 gms) was attached to one end, and by means of a similar wire, a total weight of 3317 gms in the 1st and 4763 gms in the second tests were respectively suspended at the other end. A steel metre tape was wound once round the pulley about 1 cm distant from the slipping tape and by means of a watch the time that a mark on the slipping tape occupied in passing certain distances on the metre tape was observed.

No. of Obs.	Total Distance round cms	Time of contact Pulley sec.	Errors per second	Decr. per cm.	Total dist. round cms.	Total time from start sec.	Decr. per cm.		Total dist. round cms.	Total time from start sec.	Secs per cm.	Total dist. round cms.	Total time from start sec.	Secs per cm.
					Set #1 + 1oz wt. 3317 gms				Set #2 wt. 4763 gms					
1	0·9	15			0·5	22	44	1 + 19	1.	·9	9	19	157·5	7·5
2	1·35	30		33	1.	39	34	2 + 20	2	16	7	20	158	6·5
3	1·8	45		33	·5	57	36	3 + 21	3	25	9	21	167	9
4	2·45	60		23	2.	75	36	4 + 22	4	32	7	22	176	9
5	3·00	74		25	·5	95	40	5 + 23	5	39	7	23	185	9
6	4·0	99		24	3.	114	38	6 + 24	6	47	8	24	194	9
7	4·5	112		28	·5	131	34	7 + 25	7	55	8	25	201	7
8	5·0	123		22	4.	148	34	8 + 26	8	63	8	26	211	10
9	·5	132		18	·5	162	36	9 + 27	9	72	9	27	220	9
10	6.	145		26	5.	176	32	10 + 28	10	80	8	28	228	8
11	·5	157		24	·5	191	26	11 + 29	11	88	8	29	237	9
12	7.	169		24	6.	206	30	12 + 30	12	94	6	30	247	10
13	·5	183		28	·5	218	24	13 + 31	13	102	8	31	255	8
14	8.	198		30	7.	233	30	14 + 32	14	110	8	32	265	10
15	·5	213		30	·5	249	32	15 + 33	15	119	9	33	273	8
16	9.	228		30	8.	267	36	16 + 34	16	127	8	34	283	10
17	·5	244		32	·5	285	36	17 + 35	17	135	8	35	292	9
18	10.	260		32	9.	305	40	18 + 36	18	144	9			
19	·5	278		36	·5	326	38							
20	11.	295		34	10.	342	36							
21	·5	313		36	·5	359	34							
22	12.	332		38	11·0	377	36							
23	·5	348		32	·5	392	30							
24					12.	408	32							
	Mean			28	·5	425	34					Mean		8·35

Mean 34 sec per cm.

		M phr.	ft sec	cms/sec.
Snail				
Rivers ¶				
Man walking	from amateur recs	8·17·6 / 8 $\frac{\text{hrs}}{\text{mile}}$	11.985	
Man swimming (from amateur records)		120 yds in 1 $\frac{\text{min}}{\text{yd}}$ min / 360 feet - 99·5 sec	4·022	
~~Fastest~~ International Boat Races				
✓ Man skating		¼ mile + 1320 in 35 secs / 1320 50 -	37.71	
✓ Man running		100 yds / 300 9·8 secs.	30·61	
Man bicycling		½ mile / 1320 25 secs.	52·80	
Horse galloping (racing records)		1·5 m. / 5280 in 253	51.77	
✓ Horse trotting	- -	1 m. / 5280 in 2·032 / 123	42·93	
Railroad fastest record.			112·5	
Swallows flight				4000
Projectiles				44000
Sound				33,550
Meteors			180,000	

1800

30 180,000 ft. per hr
3000
50

$\frac{112.5 \times 22}{15}$

5280
264,000

$\frac{101.5}{13000}$
3600
·03

Table of Velocities.

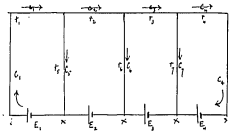
Febry. 1. 91

		miles per hr	kilometers per hr	feet per sec	cms. per sec.
Railroad train		60			2700
Swallow's flight		67 - 92			2000-9000
Projectile		672-920			3.0×10^4 to 4.0×10^4
Sound		750			33,550
Mercury's	movement in her orbit	109,358			4.93×10^6
Venus'	- - - -	83,162			$3.67 \times$ "
Earth's	- - - -	68,052			$3.04 \times$ "
Mars	- - - -	55,135			$2.46 \times$ "
Light					3.0×10^{10}
Meteors	encountering earth's atmosphere lowest	7,200			
	highest	180,000			

$c_5 = c_2 - c_1$

$c_6 = c_3 - c_2$

$c_7 = c_4 - c_3$



$c_1 r_1 - c_2 r_2 = E_1$

$c_2 r_2 + c_5 r_5 \mp c_6 r_6 = E_2$

$c_3 r_3 + c_7 r_7 - c_6 r_6 = E_3$

$c_4 r_4 - c_7 r_7 = E_4$

(85)

Standard Determinant for use in Calculating pressures and currents in Edison 5-wire systems

c_1	c_2	c_3	c_4	=	
$r_1 + r_5$	$-r_5$	0	0	=	E_1
$-r_5$	$r_2 + r_5 + r_6$	$-r_6$	0	=	E_2
0	$-r_6$	$r_3 + r_6 + r_7$	$-r_7$	=	E_3
0	0	$-r_7$	$r_4 + r_7$	=	E_4

Characteristic curve of 2½ HP Edison 91 mitis-iron completed model.

Field separately excited. For plotted curve see next page.

No. of Obs.	Current in Volts	Obsch	Amperes	Amperes (Corr.)	MMF	Volts at mot.	Ohmmeter Temp.	Amperes	Drop.	Flux per sec	E.M.F	Speed R.p.m.
1	18	1·15	5·997	2699	3390	121·5	0·274	0·214	3·4	66,900	118·1	2000
2	12	0·915	4·772	2148	2700					61,720		2050
3	9	0·722	3·817	1718	2160					62,200		2080
4	7	0·582	3·035	1366	1720					61,020		2125
5	6	0·503	2·623	1181	1485					60,370		2150
6	5	0·422	2·201	990	1245					59,800		2170
7	4	0·349	1·820	819	1030		0·293	0·229	3·7	58,420	117·8	2215
8	3	0·265	1·382	622	782		0·296	0·232	3·7	57,200		2300
9	2	0·182	0·949	427	537		0·305	0·239	3·8	55,150	117·7	2395
10	1	0·098	0·511	230	289		0·335	0·262	4·2	63,900	117·3	2680
11	0	-	-	-	-		0·669	0·524	8·4	35,350	113·1	3200

The machine comes to rest from 2900 revs. in 76 secs. after opening circuit. The mass being 19 60 gms. and the radius of gyration $\frac{11}{2}$ cms., the moment of inertia is $\frac{2{\cdot}372}{g} \times 10^5$ cm²-gms. The angular velocity $= 58000\pi$ at ~~about~~ full speed $= \frac{184220}{60}$ ~~the~~ radians per second. The angular acceleration is $-\frac{2400}{60}$ radians per sec. per sec., so that the moment of friction is $\frac{5{\cdot}60}{g} \times \frac{10^7}{60}$ dynes-cms. The energy at full speed is $\frac{2{\cdot}372}{g} \times 10^8 \times \frac{(184{\cdot}220)^2}{(60)^2}$ ergs per sec. per sec. (erg) $= \frac{9{\cdot}937 \times 10^8}{3{\cdot}6 \times 10^8}$ Joules $= 2{\cdot}73 \times 10^4$ Joules

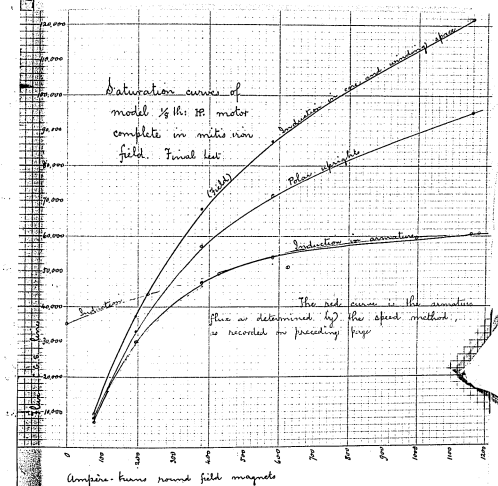
$\frac{9{\cdot}937 \times 10^8}{3{\cdot}6 \times 10^8}$

Moment of friction $2{\cdot}371 \times 10^5$ dyne cms.

$4{\cdot}312 \times 10^5$ dynes at rad. of gyration

Kinetic Energy of rotation 273 Joules light

130 " at full load.


Saturation curves of
model 1/8 H.P. motor
complete in mitis iron
field. Final test.
Induction in core and working space
(total)
Flux in pole tips
Induction in armature
Induction
The red curve is the armature
flux as determined by the speed method
as recorded on preceding page
Ampère-turns round field magnets

Magnetic Circuit Test of completed 1/8th. H.P. Motor.

2. 2. 91.

Five turns of wire were wrapped round (1) the magnet and center
(2) - four pole legs
(3) - top of the armature } between pole
(4) - bottom . . - }

and the throws on reversing the current through the field magnet observed on ballistic galvanometer with the following results —

The front side of the motor is the commutator side.

No. of Obs	Source of EMF	EMF	Coeff	q.	Mean throw	q. per turn
Obs. 15	1 B.C. @ 11°C.	1.438	1 P	1.438×10^{-7}	115.8	1.242×10^{-9}

No. of Obs	Obs. Volts	Amps.	Amp. Turns	MMF.	Mean Thro	R. of G.	q	φ	B	2φ	mean
1	0.032	0.1669	75.1	94.4	15	5250		97,800	990		
2	0.0825	0.4302	193.6	243.3	57.1			172,300	3760		
3	0.1615	0.8422	379	476.3	103.7			67,600	6,830		
4	0.248	1.293	581.9	731.5	133			86,720	8,764		
5	0.492	2.566	1155	1452	187			121,900	12,320		
6	0.032	0.1669	75.1	94.4	6			3,910	870		
7	0.0825	0.4302	193.6	243.3	24			15,650	3480		
8	0.1615	0.8422	379	476.3	42			27,380	6090		
9	0.248	1.293	581.9	731.5	52.8			34,430	7650		
10	0.492	2.566	1155	1452	72			46,950	10,430		
11	0.032	0.1669	75.1	94.4	65			4,240	940	8,150	
12	0.0825	0.4302	193.6	243.3	262			17,100	3800	32,760	
13	0.1615	0.8422	379	476.3	292.7			29,150	6480	56,520	
14	0.248	1.293	581.9	731.5	57			37,170	8260	71,600	
15	0.492	2.566	1155	1452	75.7			49,360	10,970	96,310	
16	0.032	0.1669	75.1	94.4	5.7			3,720	830		
17	0.0825	0.4302	193.6	243.3	21.8			14,200	3160		
18	0.1615	0.8422	379	476.3	38.8			25,300	5620		
19	0.248	1.293	581.9	731.5	49			31,950	7100		
20	0.492	2.566	1155	1452	66.7			43,500	9670		
21	0.032	0.1669	75.1	94.4	7			4,560	1010	5,280	5,220
22	0.0825	0.4302	193.6	243.3	28.5			18,580	4130	32,780	32,760
23	0.1615	0.8422	379	476.3	49.8			32,470	7220	57,790	57,150
24	0.248	1.293	581.9	731.5	61			39,780	8840	71,730	71,670
25	0.492	2.566	1155	1452	77			50,200	11,160	93,700	95,000
26	0.032	0.1669	75.1	94.4	5			3,260	1500		
27	0.0825	0.4302	193.6	243.3	23			15,000	6,880		
28	0.1615	0.8422	379	476.3	36			23,470	10,770		
29	0.248	1.293	581.9	731.5	42			27,390	12,570		
30	0.492	2.566	1155	1452	46.8			30,520	14,000		
31	0.032	0.1669	75.1	94.4	6			3,910	1,790	7,170	
32	0.0825	0.4302	193.6	243.3	23			15,000	6,880	34,000	
33	0.1615	0.8422	379	476.3	35.7			23,280	10,700	46,750	
34	0.248	1.293	581.9	731.5	40.8			26,610	12,210	54,000	
35	0.492	2.566	1155	1452	45.7			29,800	13,670	60,320	

First test of 120-volt 1 H.P. Motor 3rd Febr. 91.

The motor complete without base weighs 78·5 lbs. At 120 volts it runs at 1700 revs. p.m. With copper gauze brushes connecting three and occasional four bars, the current absorbed in the armature with sep. exc. field was 6 amperes. On replacing the brushes with brass gauze covering only two bars, this current fell to 5 amperes (600 watts). The diameter of the present size of wire from the commutator to the armature is 0·032". It is now proposed to employ 0·016" instead. The resistance per section is 0·1ω and of the armature, moderately warm, across one diam: 1·1ω including platinoid. Res: per section 0·2ω including platinoid. 9 layers of 11 bars in the field

Measurement of the resistivity of some samples of platinoid.

A few short lengths were cut off three coils of the wire, laid upon a porcelain scale and measured by bridge as follows:—

Ref. No.	Diameter Inches	Diameter cms.	Area sq. cms	Length	Res: Ohms by bridge	Leads.	Res: of wire's length ω.	Res: per cm.	Resistivity @ 20°C.	Mean Resistivity @20°C.	Res: per foot	Mean Resistivity @0°C.	Mean @0°C
1	0·003	0·02616	0·000537	100	7·1655	0·037	7·1285	$7·1285 \times 10^{-2}$	$3·832 \times 10^{-5}$				
2				80	5·744		5·707	7·138 "	3·837 "	$3·834 \times 10^{-5}$	$2·173\omega$		
3				60	4·315		4·278	7·130 "	3·833				
4	0·0390	0·09866	0·004262	100	0·961		0·924	$9·24 \times 10^{-3}$	3·938 "				
5				80	0·781		0·744	9·3 "	3·964 "	$3·958 \times 10^{-5}$	$2·2834\omega$	$3·913 \times 10^{-5}$	$3·898 \times 10^{-5}$
6				60	0·596		0·559	9·317 "	3·971 "				
7	0·0142	0·03606	0·001022	100	3·794		3·757	$3·757 \times 10^{-2}$	3·837 "				
8				80	3·051		3·014	3·767 "	3·847 "	$3·847 \times 10^{-5}$	$1·1467\omega$		
9				60	2·303		2·266	3·777 "	3·857 "				

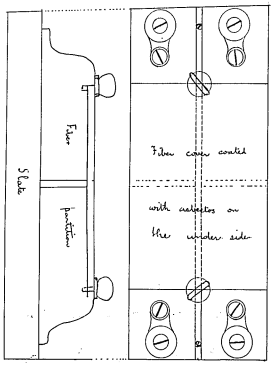
Second test of 120-volt 1 H.P. motor 3. II 91.

The platinoid wire being now 0·016" in diameter. The resistance of a single section including platinoid is 0·6ω (0·25ω each pltd. wire) and the res: across armt diameter 1·53ω. The current is 4 amp (500 watts). The poles become hot.

Rough Calculation of the power required to deposit 15 tons of copper daily from the digest of 100 tons copper ore.

The counter emf using carbon and copper in a solution of 1·15 $CuSO_4$ is 1 volt. One lb: of copper takes 38½ amp:=hrs. (say) 40. 15 tons = 30,000 lbs = 12,000,000 amperes at 2 volts = 24,000,000 Watts daily = 1000 kilowatts continuously. (500,000 emf) The source of power is distant 1·5 miles.

The surface of cathodes per ton in commercial refineries varies from 4,000 to 32,000 sq: ft:



Test of High-Tension Safety Catch Cut Out.

4th February 1891

Received a cut-out from the Engineering department, represented half size on the opposite page. A slate base 1" thick carries a pair of fibre partitions intersecting at right angles. Long fuses rest across these and these partitions serve to break the arc and keep the opposite poles apart.

Lead wire 0.065" in diam. ( ) was found to carry $\frac{2.65}{0.065}$ 19 amperes (longest fuse used). Two 7" lengths of these were inserted in the apparatus and the Municipal machine at about 1200 volts p.d. short circuited through it. The cut-out acted efficiently.

Two of these on each side were then tried on 600 volts o.k., and three of them on 500 volts with 65 amperes also o.k. The only objection is the possibility of throwing out melting lead on all sides, which under particular conditions might give rise to a conflagration. The machine should therefore be placed in a box.

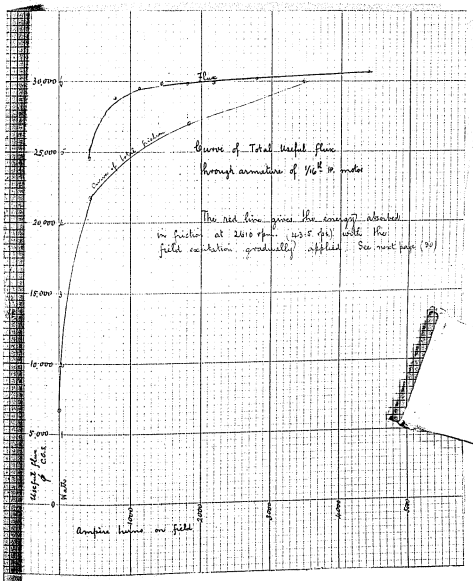
Inductance of large Wiedemann thermo-galv. coil

No. of obs.	Bridge Ratio	Res. check	Inds. + res.	Res. of coil	T.B. + coil	R.B.D.	coil to Res. Box	Inductance	Bell marked	Coefficy	Res @ 0°C.	
1	100/1	12.907	10.[illegible]	0.431	18.7°C.	4.[illegible]	4.[illegible]×10	4.[illegible] h.	0.338	0.423	0.4[illegible]	
2		12.909	10.473	0.427	18.9°C	4.665	4.690×10	4.450 h.	0.439	0.4968	0.398	

Test of 1 HP. 120 volt Motor 4th Febry. 1891.

In order to determine the origin of the waste power in this motor the machine was set in the large bank and driven by the Edison 1000-watt dynamo. The armature was not allowed to take any current, and collector ring were set over the commutator.

Ref. of Obs	Speed of motor r.p.m.	r.p.m.	Scale	Reading	Moment	6165 × moment × 10⁷	Energy absorbed Watts	Lamps in field	Volts	Amperes	Amp-hours 6916
1	1635	27.22	250	@ 7.5	1875	1.156	31	0	–	0	0
2	1590	26.5	–	@ 22	5500	3.391	90	1	0.085	0.443	307
3	1590	–	–	@ 41.5	10,375	6.398	170	2	0.158	0.924	572
4	–	–	–	@ 68	17,000	10.48	278	4	0.310	1.616	1120
5	–	–	–	@ 79	19,750	12.18	323	6	0.495	2.580	1790
6	–	–	–	@ 86	21,500	13.26	351	8	0.620	3.232	1549
7	–	–	–	@ 89	22,250	13.72	364	14	0.928	4.838	3357
		The armature wire was cut in one place and the series repeated.									
8	1660	27.66	250	@ 7	1750	1.079	29.8	0	–	0	0
9	1640	27.22	–	@ 12	3000	1.850	49	1	0.090	0.469	326
10	H.	–	–	@ 20	5000	3.083	82	2	0.180	0.938	651
11	–	–	–	@ 42	10,500	6.472	172	4	0.320	1.668	1158
12	–	–	–	@ 68	17,000	10.48	278	6	0.460	2.398	1664
13	–	–	–	@ 71	17,750	10.94	290	8	0.593	3.092	2146
14	–	–	–	@ 81	20,250	12.48	331	14	1.069	5.570	3866


30,000
25,000
20,000
15,000
10,000
5,000
0
Useful flux per cc.
Watts
1000
2000
3000
4000
5000
Ampere turns on field
70 ⁰
Curve of Watts Factor
Curve of Total Useful flux through armature of 1/4th H.P. motor
The red line gives the energy absorbed in friction at 2610 r.p.m. (43.5 r.p.s.) with the field excitation gradually applied. See next page (70)

Measurement of the resistivity of some samples of German Silver. 5th February 1891.

Took four samples of g.s. covered wire out of the stock-room and measured their resistances on the porcelain meter as follows.

No. of sample	Diameter of wire	Gauge	Area	Length	Res. observed	Leads.	Res. of wire	Res. per foot	Resistivity (cgs)	Resistivity 0°C	Res. per foot
1				100	1.331	0.0515	1.2795	1.2795×10^{-4}	2.593×10^{-5}		
2	0.020"	0.0508	0.002027	80	1.080		1.0285	1.2858	2.606		0.313
3				60	0.898		0.8465	1.4111 ?	–		
4				100	0.4355		0.3824	3.824×10^{-4}	3.563×10^{-5}		
5	0.0425	0.1077	0.009281	80	0.3610		0.3125	3.906	3.625		
6				62.5	0.298		0.2465	3.945	3.662		0.119ω
7				100	1.010		0.9855	9.855×10^{-4}	3.1612		
8	0.0261"	0.0663	0.003452	80	0.818		0.7965	995	3.4316		
9				60	0.676		0.6245	10.41	3.593	$\frac{1}{3} \times 10^{-4}$ 3.494	0.303ω
10				100	1.723		1.6715	1.6715×10^{-4}	3.428		
11	0.0201"	0.0511	0.002051	80	1.391		1.3395	1.6748	3.435	3.4168	
12				60	1.064		1.0125	1.6875	3.461		0.510ω
13				100	6.856		6.8045	6.8045×10^{-4}	3.428		
14	0.010	0.0254	0.000507	80	5.502		5.4505	6.8131	3.433	≈	2.076
15				60	4.142		4.0905	6.8175	3.434		

First Test of ½ H.P. Motor 6th Feby

Field winding) 14 layers of 66 turns = 924 turns ∓ 19 Ohlo. D.C.
" " Resistance cold = 2.38 ω @ 18°C
Inductance (armature in place + feeble battery current) = 345 h
Armature winding across brushes = 14.393 ω @ 15°C
Weight 1335 gm. Inductance (in field) = 93.58 h. Field unexcited
= 74.9 h. – excited
Resistance of one coil including pole (shunted by rest of army) = 3.9 ω @ 18°C.
Inductance = 3.235 h. unexc. field
= 2.17 h under exc. pole pieces
= 0.75 h between poles.

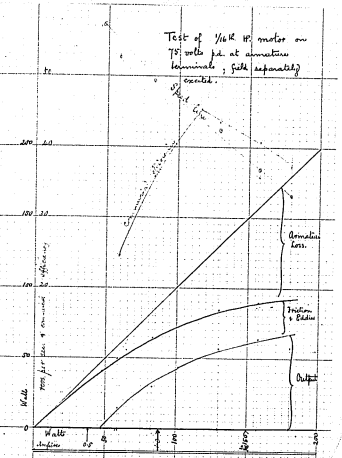
Tests 7th Feby Motor running light with exp. exc. field on 65 volt cct.

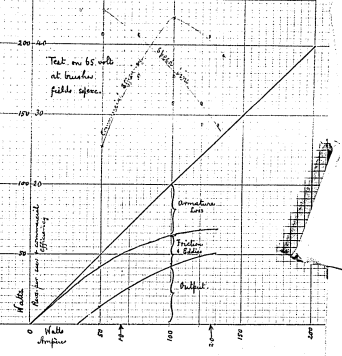
No.	Setting of cct.	Lamps in field cct.	Ring: tow.	Amp:	Amp: turns	MMF	Speed R.p.m.	Speed R.p.s.	Clock time	Current in army.	Drop in army. volts	EMF generated volts	EMF per foot volts	4185 f
1		12	0.28095	6.750	4389	5517	2327	38.8	0.126	0.637	9.53	49.5	1.276	30,690
2		8	0.39976	3.002	2776	3490	2120	40.3	0.110	0.574	8.3	50.7	1.258	30,260
3		6	0.31370	2.363	2183	2744	2140	40.7	0.180	"	"	"	1.246	29,970
4		5	0.25862	1.947	1799	2262	2147	40.8	"	"	"	"	1.243	29,900
5		4	0.20800	1.566	1447	1819	2180	40.8	"	"	"	"	1.243	29,900
6		3	0.16296	1.227	1134	1425	2180	41.3	"	"	"	"	1.229	29,540
7		2	0.11394	0.858	793	997	2540	42.3	"	"	"	"	1.199	28,840
8		1	0.06116	0.461	426	536	2840	47.3	0.194	0.73	10.6	48.14	1.023	24,600
9		0	–	–	–	–	–	–	–	–	–	–	–	plateau 2.15 m.l.

With the current cut off the field, the speed at first reached about 3500 r.p.m. (from there above) declined, stopped and recommenced in the opposite direction.

Field of motor & also of dynamo separately excited

No. of obs.	P.D. at M.T. v.	Watch tam.	Ampere in arm.	Energy in watts w.	Current thro' field	Amp. turns on field	Drop. in arm. v.	E.M.F. generated by arm. e.	Loss of energy in arm. w.
1	60	0·110	0·574	34·4	1·266	1664	8·6	51·4	4·9
2	65·6	0·1145	0·786	49·6			11·3	54·3	8·5
3	64·2	0·210	1·095	70·3			16·4	47·8	18·0
4	64·2	0·296	1·544	99·1			23·2	41·0	35·8
5	64	0·360	1·877	120·1			28·2	35·8	52·9
6	63·1	0·400	2·086	131·7			31·3	31·8	65·4
7	74	0·465	2·425	179·4			36·4	37·6	88·2
8	74·2	0·405	2·112	156·7			31·7	42·5	66·9
9	74·5	0·333	1·737	129·4			26·1	48·4	45·3
10	75	0·21	1·095	82·1			16·4	58·6	17·9
11	75	0·15	0·782	58·6			11·7	63·3	9·2
12	75	0·12	0·626	47·0			9·4	65·6	6·0
13									





Test of 1/16 H.P. (50 Watt) Motor 7.II.91.

Motor balanced in bank and driven by a 1/8 H.P. c.r.c., with usual connection. The friction was observed with the field varied and removed as follows.

	Speed r.p.m.	Speed r.p.s.	Ring. low amp.	Ring. amp. (0.1258)	Amp. low amp.	Balance Eq. @	Balance Moment	6165 × moment	Energy absorbed		
1	2610	43.5	0	0		1	50	3.13×10⁶	1.34		
2	"	"	0.06554	0.4494	456	3.2	160	9.866	4.3		
3	"	"	0.12279	0.925	855	"	"	"	"		
4	"	"	0.17633	1.328	1227	"	"	"	"		
5	"	"	0.26328	1.983	1832	4	200	1.233×10⁶	5.4		
6	"	"	0.49858	3.755	3469	4.5	225	1.387	6.0		

For the plot of these results see the curve sheet of the preceding page.

Efficiency test: Motor driving 1/8 H.P. c.r.c. Supplied with 65 volts.

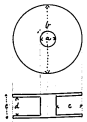
Energy consumed in effort w.	Speed r.p.m.	Speed r.p.s.	Balance.	Moment	Moment 6165	Energy absorbed w.	Friction (effort − add)	Effic. η	Comm. η.
29.5	2480	41.33	50 @ 0.0	0		0	29.5	0.857	
41.1	2698	44.97	50 @ 9.1	455	2.805×10⁶	12.6	28.5	0.829	0.254
42.0	2486	41.43	50 @ 19.6	975	6.01	24.9	27.4	0.744	0.354
63.3	2130	35.5	50 @ 19.8 100 @ 10	1975	12.18	43.2	20.1	0.639	0.436
67.2	1905	31.75	50 @ 25.5 100 @ 15	2525	15.57	49.4	17.8	0.560	0.411
66.3	1719	28.65	50 @ 27.2 100 @ 15	2860	17.63	50.5	15.8	0.503	0.384
91.2	1983	33.05	50 @ 35.4 100 @ 15	3270	20.16	66.6	24.6	0.508	0.371
84.8	2208	36.8	50 @ 36.1 100 @ 15	2805	17.30	63.7	25.1	0.573	0.407
54.1	2539	42.32	50 @ 23.2 100 @ 15	2160	13.32	56.3	27.8	0.650	0.425
64.2	2962	49.37	50 @ 19.5	965	5.95	29.4	34.8	0.782	0.358
49.5	3160	52.67	50 @ 8.9	445	2.74	14.4	35.1	0.843	0.248
41.0	3426	57.1	–	0		–	41.0	0.872	–

Dimensions and Data of Search Coil 10th Feby 91.

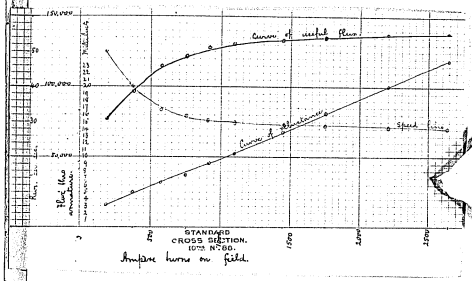
a = 0.64 b = 2.520 c = 0.910 d 0.805 e = 1.14

3278 turns + of 0.002" (0.00508) copper wire

connect to 0.0



φ	ρ volts	E (from Exc.-C.)
138,700	23.9	16,240
137,200	20.1	16,060
135,800	16.25	15,800
133,000	13.6	15,610
130,300	10.4	15,260
128,200	9.0	15,010
122,300	7.7	14,320
114,900	6.3	13,460
96,580	4.9	11,310
77,560	3.13	9,080



Test of ¼ H.P. Motor 9th February 1891.

This motor weighs complete, with pulley 28 ℔ 1oz.
The armature is wound with 302 ft wire each 0.018" cond. to 0.0265".
The field is wound with 450 turns of wire 0.049" cond. to 0.061"
The resistance of the field is 1.05 ω @ 18° C.
" inductance " " " 133.6 h with the armature in place and using testing current.
" resistance " " armature between brushes is 9.1 ω @ 18° C.
" " " " " " 10.25 ω hot
" inductance " " " " "
" resistance of one coil of the armature without the platinoid wire is 0.80 ω cool.

Platinoid wire 0.0075". Brass 0.051 (0.052) Separately exciting and 121 v. a mk.

1st Test. Characteristic curves.

Ref. No.	Weight kgm.	Amperes	Amp. turns. ×450	MMF	Lamps in field cct.	Speed r.p.m.	Speed r.p.s.	Rising kgm. ×0.1338	Amperes in arm.	Drop in arm.	EMF generated	EMF per amp.
	1.125	5.866	2640	3320	15	1680	28.0	0.05216	0.395	3.6	117.4	4.194
2	0.935	4.876	2194	2758	12	1700	28.3	-	-	-	-	4.148
3	0.748	3.901	1756	2207	10	1715	28.6	-	-	-	-	4.105
4	0.615	3.207	1443	1814	8	1750	29.2	-	-	-	-	4.020
5	0.461	2.405	1082	1360	6	1790	29.8	-	-	-	-	3.940
16	0.39	2.034	915	1150	5	1820	30.3	-	-	-	-	3.940
7	0.32	1.669	751	944	4	1900	31.7	0.0553	0.417	3.8	117.2	3.875
8	0.246	1.283	577	725	3	2020	33.7	0.0582	0.439	4.0	117.0	3.697
19	0.159	0.829	373	469	2	2395	40.0	0.0612	0.461	4.2	116.8	3.473
20	0.092	0.428	193	243	1	2990	49.8	0.0612	0.461	4.2	116.8	2.345

2nd Test. Friction test.—
When running at 1770 r.p.m. the following observations were made.

No. of Obs.	Initial Speed r.p.s.	Initial angular velocity	Condition during stoppage	Angular Acceleration ~~rad.~~	Time of stopping sec.	Mass of arm.	Effective rad. of friction	Moment of journal friction (gm-cm)	Moment of brush friction (gm-cm)	Moment of eddy current friction (gm-cm)	Moment of hysteresis estimated	
1	29.5	185.3	Field off, brushes off	3.25	57	2640 gm	6 cms.	309.		Field (309)	9.586×10^4 cm² gm.	
2	-	-	Field off brushes on	6.18	30			~~589~~	279	(279)		
3	-	-	Field on	12.35	15					586 (1175)		

Floated motor, drove it from the Edison 250-watt machine.

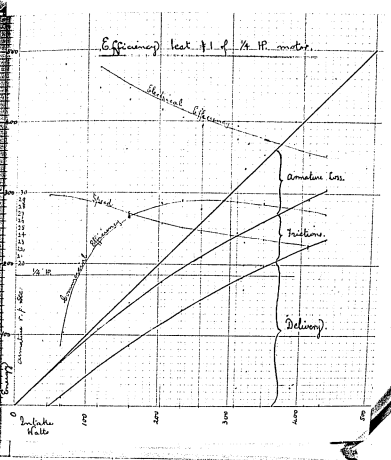
Ref. No.	Speed r.p.m.	Speed r.p.s.	Lamps cct. of field	Amp. turns.	MMF	Balance	Moment	Gives × (Moment Watts)	Watts Losses per sec.	Moment of friction (Watts)	
1	1860	31	0	~~1440~~		50 @ 18.2	910	174	0.56	0.92	
2	-	-	1	193	243	80 @ 24.8	1240	23.7	0.76	1.210	
3	-	-	2	373	469	100 @ 16. / 50 @ 13.7	1685	32.2	1.04	1.656	
4	-	-	3	577	725	100 @ 20 / 50 @ 21.0	2050	39.2	1.265	2.014	
5	-	-	4	751	944	100 @ 20 / 50 @ 22.5	2250	43.0	1.39	2.214	
6	-	-	5	915	1150	100 @ 20 / 50 @ 24	2450	46.8	1.51	2.405	
7	-	-	8	1443	1814	100 @ 20 / 50 @ 25.2	2610	49.9	1.61	2.564	

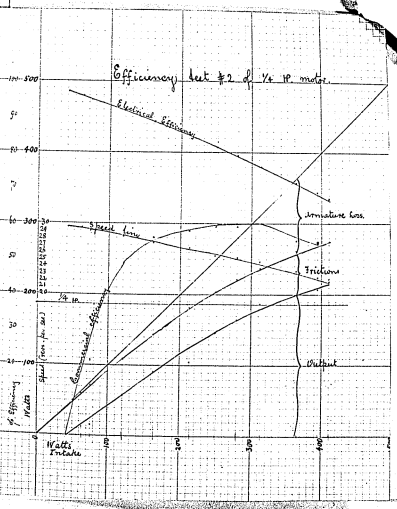
No. of Obs.	P.D. at motor terms	Watch	amperes	Energy in motor	Rev. of arm	Drop in arm	Energy wasted in arm	E.M.F. generated	Energy exerted in effect	Speed rpm	r.p.s.	E.M.F. per rev per sec
1	124.0	0.10	0.522	64.7	9.10	4.75	2.4	119.3	62.3	1767	29.45	4.051
2	122.0	0.105	0.548	66.9	9.3	5.1	2.8	116.9	64.1	1760	29.33	3.986
3	121.2	0.186	0.970	117.5	9.5	9.2	8.9	112.0	108.6	1707	28.45	3.936
4	120.5	0.255	1.33	160.2	9.7	12.9	17.1	107.6	143.1	1618	26.97	3.990
5	118.3	0.329	1.716	203.0	9.8	16.8	28.8	101.5	174.2	1545	25.75	3.942
6	117.2	0.380	1.982	232.3	9.9	19.6	38.8	97.6	193.5	1505	25.08	3.893
7	116.2	0.428	2.232	259.3	10.0	22.3	49.7	93.9	209.6	1460	24.33	3.860
8	120.	0.495	2.581	309.7	10.1	26.1	67.3	93.9	242.4	1470	24.5	3.833
9	118.1	0.566	2.951	348.5	10.2	30.1	88.9	88.0	259.6	1405	23.4	3.760
10	119.7	0.660	3.441	411.8	10.3	35.4	121.7	84.3	290.1	1350	22.5	3.747
11	123	0.675	3.535	434.8	10.3	36.4	128.5	86.6	306.3	1350	22.5	3.850
12	121	0.-	0.395	47.8	9.1	3.5	42.4	117.5	46.4	1770	29.5	3.983

The motor was then taken apart and the platinoid wire exchanged from 0.0073 to 0.0065. The resistance of each wire is now 0.0176 ~~0.0176~~
Resistance of armature across a diameter 11.24 including platinoid wire
" " " 8.64 excluding " "
" " " 9.81 including " "

No. of Obs.	P.D. at Motor terms	Watch	amperes	Energy	Rev. of arm	Drop in arm	Energy wasted in arm	E.M.F. generated	Energy exerted in effect	Speed rpm	r.p.s.	E.M.F. per rev per sec
1	120.5	0.066	0.344	41.5	9.80	3.4	1.2	117.1	40.3	1770	29.5	3.97
2	"	0.100	0.522	62.9	9.9	5.2	2.7	115.3	60.2	1768	29.47	3.91
3	122.5	0.120	0.626	76.7	10.0	6.3	4.0	116.2	72.7	1745	29.1	3.99
4	"	0.188	0.980	120.1	10.1	9.9	9.5	112.6	110.3	1690	28.17	4.00
5	119.25	0.261	1.361	162.3	10.2	13.9	19.5	105.4	143.5	1645	27.4	3.85
6	120.5	0.340	1.773	213.6	10.3	18.3	32.5	102.2	181.1	1600	26.67	3.83
7	119.25	0.400	2.086	248.8	10.5	21.9	45.6	97.4	203.2	1545	25.75	3.78
8	119.25	0.450	2.347	279.9	10.7	25.1	58.8	94.2	221.1	1512	25.2	3.74
9	119	0.500	2.623	313.4	10.9	28.7	75.6	90.3	237.8	1477	24.6	3.67
10	119.5	0.585	3.051	364.6	11.1	33.9	103.5	85.6	261.1	1400	23.3	3.67
11	119	0.660	3.442	409.6	11.3	38.9	133.9	80.1	275.7	1345	22.4	3.58
12	119	0.638	3.327	395.9	11.3	37.6	124.9	81.4	271.0	1315	21.9	3.72

There was less spark at the brushes on full load.
When running at 1765 rpm the armature stops in 23 seconds with field off brushes
63.5 " " " " " off
11.0 " " " on " on
12.25 " " " " " off





Tests of ¼ H.P. Motor (Efficiency test #1) 9.12.91
Motor floated, and its fields separately excited, driving the 250 watt Edison Library model. Results as follows:

Balance	Moment	6165 × Moment	Delivery Watts	Comm. efficiency	Elect. Efficiency	Ring torq.	amps in field 0.328	A.T. on field	Friction	Condition	Remarks in dynamo
50 @ 12.0	600	3.699	10.9	0.169	0.962	0.3072	2.917	1312	51.4	dyn. light	
{500 @ 10 50 @ 15.2}	760	4.686	13.7	0.205	0.958				50.4	dyn. S.E.F.	
{500 @ 5 50 @ 13.2}	3160	1.9148	55.4	0.472	0.953				53.2	1 λ	
{500 @ 10 50 @ 23}	5115	3.153	85.0	0.531	0.893				58.1	2	
{500 @ 15 50 @ −4.2}	7285	4.491	115.6	0.570	0.858				58.6	3	
{500 @ 15 50 @ 24}	8700	5.364	134.5	0.579	0.833				59.0	4	
{500 @ 20 50 @ −0.5}	9.600	5.918	144.	0.556	0.805				59.6	5	
{500 @ 20 100 @ 10 50 @ 16.5}	11,825	7.290	178.5	0.577	0.783				63.9	6	
{500 @ 20 100 @ 25 50 @ 26.2}	13.835	8.528	199.5	0.573	0.746				60.1	8	
{500 @ 15 50 @ 29}	16,400	10.11	227.5	0.553	0.704				62.6	10	
{500 @ 15 50 @ 29.3}	16,935	10.43	234.7	0.540	0.704				71.6	10 with lighter load	
—	—	—	—	—	0.971				46.4	after 2 hours run.	

There was a little too much sparking at full load.

Balance	Moment	6165 × Moment	Delivery Watts	Comm. eff.	Elect. Eff.	Ring torq.	amps in field	A.T. on field	Friction	Condition	
50 @ 0	0				0.97	0.387	2.917	1312	40.3	clus:	
50 @ 14.2	710	4.377	12.9	0.205	0.957				47.3	dyn. light	
50 @ 18.3	915	5.641	16.4	0.214	0.948				56.3	dyn. S.E.F.	
{100 @ 20 50 @ 27.5}	3375	2.081	59.6	0.488	0.918				51.7	1 λ	
{500 @ 10 50 @ 7.4}	5370	3.311	90.7	0.56	0.884				52.8	2 λ	
{500 @ 15 50 @ 0.4}	7520	4.637	123.7	0.58	0.848				57.4	3 λ	
{500 @ 20 50 @ −12}	9250	5.703	146.9	0.59	0.817				56.3	4 λ	
{500 @ 20 50 @ 12.5}	10,625	6.550	165.0	0.59	0.790				56.1	5 λ	
{600 @ 20 50 @ 7.8}	12,390	7.638	188.0	0.60	0.759				59.8	6 λ	
{1000 @ 10 200 @ 5.5 50 @ 27.5}	13,875	8.554	199.3	0.55	0.716				60.8	8 λ	
{1000 @ 10 1000 @ 5 50 @ 0.1}	15,850	9.772	219.0	0.535	0.673				56.7	10 λ	
{1000 @ 10 1000 @ 5 50 @ 5.5 50 @ 0.5}	15,435	9.516	205.4	0.526	0.684				62.6	10 λ	after 2 hours

Determination of Series Field-Winding for ¼ H.P. motor

Allowing 375 A.T. for light load with 0.46 amp. = 815 turns.
The diameter of the core above insulation is 1.72", the ext: diam: 3.3".
The mean diameter of winding 2.5" = 7.55" = 0.654' ∴ 815 turns = 533'.
The weight may be 2.5 lbs: at most = 21.32' per lb. = either 19 or 20 B.W.G.
2.5 lbs. of #19 @ 1.25 w per lb = 3.1 w drop at 3 amp: 10 volts
2.5 - - #20 @ 2.6 w - - = 6.5 w - - 3 - 19.5 -
The interflange being 4" 0.7854 (4² − 1.72²) × 4 = 2.5 × 5.55 ∴ x =
2.5 lbs of #19 @ 187' per lb = 467.5'
3.0 lbs. of #19 @ 157' - - = 561' = 3.75 w drop at 3 amp 11.25 v. energy 33 w

Friction test of 1/16 H.P. motor after fitting with solid pole-pieces.
12.5 Feb. 91

The motor was separately excited and driven by the Library 250 volt motor. The 1/16 H. field was varied and power absorbed noted —

Tot Obs.	Obsch	Amp.	Amp turns	Amps	Speed of arm: r.p.m.	r.p.s.	Balance	Moment	0.165 × Moment	Energy	Condition
1	0	-	-	-			50 @ 2.0	140		2.47	Brushes lifted
2	0	-	-	-	1720	28.83	- @ −2.6	280		4.37	-
3	0.081	0.423	391	1			@ −8.8	540		9.52	-
4	0.152	0.793	733	2			@ −11.0	650		11.46	-
5	0.240	1.251	1156	3			@ −11.3	665		11.73	-
6	0.308	1.606	1484	4			@ −11.4	670		11.82	-
7	0.575	3.000	2772	8			@ −11.8	690		12.17	-
8	0.710	3.703	3420	10	1705	28.42	@ −12.0	700		12.35	-
9			3420	10	1705	28.42	@ −15.2	861		15.18	Brushes down
10			2772	4			@ −13	750		13.23	-
11			1156	3			@ −12.5	725		12.79	-
12			391	1			@ −12	700		12.35	-
13			-	0	1730	28.83	@ −6.9	445		7.85	-
14				0	~~1730~~						

(Solid poles) Increasing the amp. turns from 0 to 3400 adds 7.4 watts to the friction
(Laminated) - - - - - - - - - 4.7 - - -

On the resistance of platinoid wire drawn by mm. gauge.

Diameter cm	Inches	Area sq. cm	c. mils.	Resistivity assumed.	Res. per cm	Res. per foot	Res. per cm. obsd.	Res. added to arm: (effective)
0.010	0.00394	0.000078539	15.52	4.037×10^{6}	5.14×10^{9}	15.66		
0.012	0.00473	0.000113.1	22.37	3.44×10^{6}	3.57 -	10.88 9.27	3.042×10^{9}	
0.014	0.00551	0.000153.9	30.36	3.41×10^{6}	2.624 -	8.00 6.79	2.216	
0.016	0.00630	0.000201.1	39.69	3.38×10^{6}	2.007 -	6.12 5.12	1.680	
0.018	0.00709	0.000254.4	50.26		1.606 -	4.894		
0.020	0.00787	0.000314.2	62.09		1.285 -	3.916		

Field winding adopted on ¼ H.P. motor 14 layers of 66 turns each (924 turns) of 0.042" wire #19 B.W.G. s.c.c. to 0.051".

No. of Obs.	P.D. across	Amps.	Watts in water	Energy in water	Volts of field	Watts in field	Energy in field	Energy in armature	Volts of armature	Drop in armature	Energy lost in armature	efficiency of effect
1	118·5	0·105	0·545	64·6	2·32	1·27	0·70	63·9	9·45	5·18	2·8	61·1
2	119·0	0·132	0·658	81·9	2·33	1·60	1·1	80·8	9·60	6·61	4·5	76·2
3	120·0	0·144	0·751	90·1	2·34	1·76	1·3	88·8	9·75	7·32	5·5	83·3
4	120·5	0·235	1·226	147·7	2·35	2·88	3·5	144·2	9·90	12·13	14·9	129·3
5	120·0	0·298	1·538	184·6	2·36	3·63	5·6	179·0	10·05	15·46	23·8	155·2
6	120·0	0·359	1·872	224·6	2·37	4·44	8·3	216·3	10·20	19·10	35·8	180·5
7	121·0	0·409	2·133	258·1	2·35	5·08	10·8	247·3	10·35	22·07	47·1	200·2
8	120·0	0·466	2·539	304·0	2·39	6·06	15·4	288·6	10·60	26·86	68·1	220·5
9	118·5	0·540	2·816	334·6	2·41	6·79	19·1	315·5	10·85	30·58	86·1	229·4

PARTICULARS OF EDISON MODEL 1/4 HORSE POWER MOTOR.

Weight without wooden base 26 3/4 lbs.
with wooden base 28 3/4 lbs.
Winding gramme-ring and series field.
Voltage 120 at terminals
Amperes at delivery of 1/4 HP. 3.0
running light 0.55
Commercial efficiency at delivery of 1/2 HP. 50%
" " " " " 1/4th. H.P. 50%
" " " " " 1/8 HP. 54%
Speed running light 2500 revs. per min.
at delivery of 1/4 HP. 1300 revs. per min.
Dimensions :-
Armature body diameter external 6" internal 4"
Number of grooves 42 on each side.
Breadth of armature body over teeth 1.182"
at base of grooves 0.662"
Depth of grooves 0.26", breadth of grooves 0.26"
Band iron in core 0.029" annealed.
Cross-section of armature core 0.66 sq. ins. , 4.29 sq. cms.
breadth of teeth 0.21" at external, 0.06" at internal circle.
Insulation 0.01" mica and 0.005" oiled silk or paper.
Polar surface of teeth 20 sq. cms. under each pole.
Winding 42 turns , 3 layers of 14 turns each of 0.06 [illegible]
0.018" covered to 0.0235"
Commutator diys. 42.
Total length of wire in armature 1000 feet.
Total weight " " " " 1.0 lb.
Resistance of armature between brushes 3.0 ohms [illegible]
Same including g.s. connections 3.5 " [illegible] " "
Current in armature at full load 3.0 amperes
Drop in armature " " " 12 volts.
Foreign expenditure in heating armature [illegible] 10 watts.
Magnetic flux 55.5 [illegible] cms. lines.
Induction density in core [illegible] 11000.
Field magnet of [illegible] [illegible] per pole [illegible] 4 segments
Core diameter 1.05" [illegible] 4.0"
Diameter over wire 4.0"
Flux through core center at full load 200,000
Induction density of core at full load [illegible] 10,000.
Winding 600 turns of wire 10 layers.
Wire # 19 B.W.G. 0.042" covered to 0.054" 2 lbs.
Resistance of field winding 2.3 ohms [illegible]
Drop in field at full load 6.72 volts. [illegible]
Total resistance of motor between terminals [illegible] ohms
Brushes of copper gauze under the blocks of carbon.
Gap [illegible] from armature to commutator g.s. 0.100"

Final test of 1/4 H. P. Motor
on 120 volts.
Electrical Efficiency
Mechanical Efficiency
Full Load
Armature losses
Friction
Pull
Delivery
Intake Watts
0
100
200
300
400
Delivery Watts
Pull Lbs.
Efficiency %

Final Tests of ¼ HP Motor 13th – 14th February

The field winding was adjusted to 1lb. 15 oz. of # 19 BWG 0.042" to 0.051". (Leaving 10 layers of 66 turns or 660 turns in all. Series wound

8 (Efficiency) test driving Library model, 250 Watt machine sepi. exc.

Speed r.p.m	r.p.s.	Balance ⊙	Moment	6165 Moment	D. drag w.	Friction Tick w.	Gross eff.	Elect. eff.	EMF generated	Amps. Turns	Output
2535	42.25	50 ⊙ 0	0				42.3	0.945	112.0	361	Lights dim
2125	35.42	50 ⊙ 24	1200	7.4×10⁶	26.05	0.318	50.1	0.931	110.8	454	Lights
2070	34.5	50 ⊙ 26	1300	8.01 "	27.6	0.337	55.7	0.925	111.0	496	S.E.R.
1825	30.42	{50 ⊙ 20, 100 ⊙ 25}	3500	2.158 "	65.6	0.444	63.7	0.877	105.6	809	1 λ
1645	27.4	{500 ⊙ 3, 5000 ⊙ 10}	5450	3.360 "	92.1	0.499	63.1	0.841	100.9	1015	2 λ
1530	25.5	{50 ⊙ 15, 500 ⊙ 15}	7875	4.670 "	119.1	0.530	61.4	0.812	97.5	1235	3 λ
1470	24.5	{50 ⊙ 17, 500 ⊙ 20}	9450	5.827 "	142.8	0.553	57.4	0.776	93.9	1408	4 λ
1365	22.75	{50 ⊙ 17, 500 ⊙ 25}	11,750	7.244 "	164.8	0.542	55.7	0.726	87.1	1673	6 λ
1280	21.33	{50 ⊙ 19.5, 500 ⊙ 25}	13,450	8.316 "	177.4	0.530	52.0	0.682	69.1	1858	8 λ

There was a little harmless sparking at the brushes during full load.

20 y in field = 5460 y-turns per opent = 10920 AT per col = 13720 MMF
1240 volt = 1753 Max: on S. H.
20.2 × 16 × 512 = 1.655 × 10^5 flux
1753 ÷ 1.655 = 1.059 × 10^6 flux
13720 ÷ 1.059 = 1.296 × 10^-2 lines.

Test of the Alternator described on p. 138 Book III.

Schenectady 16th February.

The polar circle has been bored out to 22 3/8 + Bands 3/4" wide of #19 B.W.G. phosphor-bronze wire on 1" mica.
res: of the field is 0.87 ω @ 15.5° C.
" " " armature is 1.2 ω.
weight of the armature complete
" " " field frame.

When running at 1212 revs. on the first occasion, the bands flew off the armature. On this account the field was bored out to its present dimensions. Bands of 1mm of phosphor-bronze wire 0.6 were then laged on soldered.

When running the second time at 1212 revs. with 120 volts on the field and a Cardew voltmeter of 566 ω across the poles in circuit with 7782 ω of inductaneless wire making a total of 8350 ω multiplying power of 14.7 the volts shown (effective) were 83 = 1240 effective volts. 12 lamps were also brought up to candle power. Within a few seconds however, the bands burst from the armature, almost destroying it.

Test of No 2 Edison Experimental A.C. Motor

The motor with its field rearranged as described on p. 131 Book III.
The fields were excited from 500 volts, and 500 volts also through the armature. 512 bars in commutator + 4 brushes of brass plates.

With 500 volts on field	1.83 amperes	110 volts on armature		56 rpm.
" "		500 " " "		248 rpm
	1.1 "	500 " " "		300 " "
	0.7 "	500 " " "		400 " "

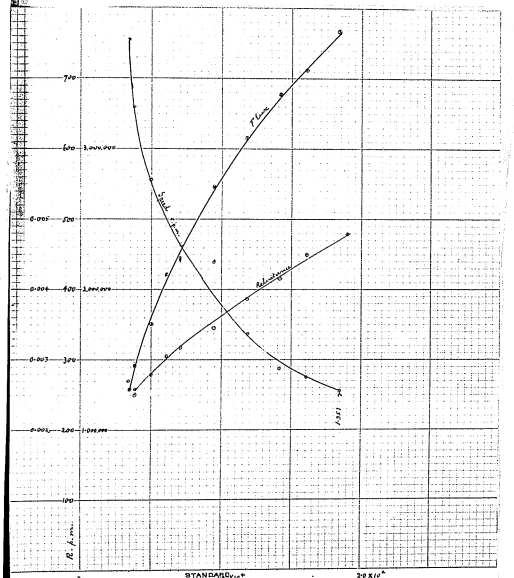
Test of the Alternator continued 17. II. 91.

The tendency of the fields to rise in temperature, under excitation was determined with the armature removed. On starting, the EMF on the coils was 120 v the current 25 ~ and res: of all coils in series 5.2 ω. after 65 min, the p.d. was 121 v, the current 22, and the res: 5.5 ω, after 4 hours, the p.d. was 120 the current 18.5, and the res: 6.49, a rise of 24.8% = 64° C. The temp: by thermometer on the coils ~~was~~ reached the maximum limit of 85° C = 70° C rise. One coil was found to be partly short-circuited, even at the commencement of the test.

The armature was patched up, and bound with 3 ply phosphor bronze wire bands in widths of 4, soldered only on the outside wire. In running the armature at 1280 rpm, there was an initial clearance of about 1/8" all round. After raising the field slowly to full power, it shortly became evident that some part of the armature was rubbing against the poles, and on stopping, the armature was found to have ~~been~~ enlarged radially.

The Westinghouse alternators run at about 1650 rpm and their armatures are 21" in diam: (approx:) = 9075' per min.

r	φ
4.79×10⁻⁹	3.839 ×10⁻⁶
4.51	3.598
4.16	3.348
3.84	3.072
3.45	2.734
3.19	2.220
3.05	2.106
2.79	1.756
2.51	1.501
2.37	1.468
2.10	1.392



STANDARD 10" CROSS SECTION.
Tunnel = A. Tunnel x 1.257
10" N.B.

Determination of the winding for the #2 motor clutches when inserted in the field circuit. 19th Feby. 91.

From the record of page 76 it is evident that 2000 amp. turns are needed in each clutch. Allowing 1.75 amp. in the circuit, the no. of turns = 1140. The mean radius being 7.5", the circumference is 47" say 4'. so that the total length is 4560' of wire. The winding space is 47 × 0.925 × 1.8 = 78.4 c.in. = 14 lbs. 14 lbs for 4560' = 326' per lb. = #21 B.W.G. 0.032" s.c.c. & 0.041". = 22 turns and 44 layers = 970 turns = 3580' = 11.6 lbs. say 12 lbs. of #21 B.W.G. @ 4.19 = per lb. = 50 ~ each = 100 ~. This is prohibitive.

Allowing 500 amp. turns. @ 1.7 amp = 300 turns = 1200' = 185' per lb. = #17 B.W.G. 0.054" cond. & 0.078". = 12 turns and 25 layers = 300 turns. 14 lbs. of this wire. @ 0.26 per lb. = 3.64 ~ for in series.

Allowing 800 amp. turns @ 1.7 amp = 470 turns. = 1880' at 13 lbs. = 144' per lb. #18 B.W.G. 0.049" cond. & 0.059" = 16 turns + 32 layers = 512 turns. at 12 per lb. = 132' per lb = #18 B.W.S. 0.051 cond & 0.061" = 15 turns × 30 layers = 450 turns. 14 lbs @ 0.66 & per lb. = 9.24 ~ each = 18.48 ~ in series.

Test of the #2 S.C. motor in the new field
19th February 1891.

This motor is mounted in the fields described on p. 131 Book III.
The following observations were made:—

Field speed 37.00 turns accumu.

No.	P.D. on motor	Speed	Speed reduced to 800 r.	Current in field	Current in armat.	No. of armat.	Drop in armat.	EMF of armat.	Ampers of field	Remarks	Amp T.
	v	r.p.m.		j	a	v	v	v			
1	512	260	254.6	1.95	1.05	1.53	1.4	510.6	262.5	No sparking	14,630
2	-	280	274.5	1.7	1.5	2.0	2.0	510.		- 1.603	12,750
3	-	294	287.5	1.5	1.7		2.3	509.7		- 1.414	11,250
4	-	324	318.1	1.25	1.95		2.6	509.4		- 1.179	9,375
5	-	364	357.4	1.0	2.0		2.7	509.3		- 0.9428	7,500
6	-	448	440.1	0.75	2.25		3.0	509		- 0.7071	5,630
7	-	472	463.8	0.68	2.32		3.1	508.9		- 0.6532	5,100
8	-	566	556.2	0.52	2.3		3.1	508.9		- 0.4243	3,900
9	-	662	651.0	0.4	2.6		3.5	508.5		- 0.3771	3000
10	520	688	665.6	0.4	2.4		3.2	516.8		- 0.3771	3000
11	524	784	756.0	0.37	4.0		5.3	518.7		- 0.3491	2775
12	During a power test of this motor it was found to deliver a dynamometer pull of 400 lbs reducing on motor to 2500 lbs on a train of cars with a current decreasing from 94 to 60 amp.										

Sparking experiment.

Motor running at 500 volts t.p.d.

1.85 amp. in field	2.2 in armat.	256 r.p.m.	
0.65	27		no sparking appreciable
0.4	45		some but not bad sparking
0.30	62	668	
0.38	72	734	

Results of brushing the 20. Kilowatt machine at Schenectady, with 1/16" cylinder all round the poles.

With 200 amperes 40°C rise after 2¾ hours trial before brushing.
" 320 " 39°C " 5 " " after "

Test of the Carrying Capacity of Carbon brushes 20.II.91

A Sprague armature was disconnected from it commutator. This commutator was lapped with about 100 turns of fine copper wire on its ~~inner~~ rim to connect all the bars together. The diameter is 6", (the periphery 19"). 56 bars separated by mica scant 1/16" wide. The brushes were of carbon very slightly copped 1 3/4 x 1 3/4 x 1/2" and held in the brush holder up to about 1/4" from the commutator. By means of a pulley and belt, this armature was run from a motor and current passed between the brushes. There was comparatively little sparking up to 100 amperes on these brushes offering a measured contact surface of 3/4 sq. in. between 992 and 1312 revs.

At 1312 revs. per min.	and 105 amp.	the p.d. across brushes was	6.2 v = 0.06 ω
	75		5.8 v = 0.075 ω
	50		4.1 v = 0.082 ω
	20		3.0 v = 0.100 ω
at 1100	100		5.8 v = 0.058 ω
	75		5.2 v = 0.07 ω
	50		4.2 v = 0.084 ω
	35		3.6 v = 0.103 ω
	25		3.2 v = 0.128 ω

Data Concerning Street Railroads obtained on the 20th Feby.

Weight of the Westinghouse ordinary cast. iron		15 HP. motor + gears	2570 lbs.
" " " Sprague No. 6.		15 HP	1600 "
" " " #2 new Edison experimental		30 HP	4240 "

The average at Pittsburg of current by ammeter with 58 cars out (Sprague car) was 580 amperes (10 per car) with 500 v. station pressure falling to a mean of 450 in the morn.

The W. + T.H. motors average about 17 amp. per car owing to the use of resistance in the armature circuit.

The use of iron link wire between rails is unobjectionable. Rails should also be frequently grounded, this saves interference with telephonic systems.

Sprague no. 6. motors are tested for one hour with a steady current of 25 amperes. The usual temp attained on the armature is 50 – 55° C. about 35° C. rise.

Sprague motors occasionally take 100 amperes each for short intervals.

Westinghouse motors will run on light loads up to 20 miles p.h.

All motors in street car service employ Series Fields.

For the first three or four days the wheels spark on the track when electric cars are first introduced on a line, after that, the only source of bad contact is generally dry snow.

T.H. motors will run at 8 m.p.h. without rev. inertia.

The average schedule speed of motor cars in Pittsburg including stoppages is 6 mph. In the suburbs, and early or late, in the city it attains 12 mph.

Whenever a single motor car is geared to one axle only, the car fails to mount grades in slippery weather. The fact does not give rise to much annoyance because sand is thrown on the rails.

All the parts of a motor are subjected to severe mechanical strain and vibration, and frequently cases in the fields of a Sprague are traceable to loosening of the magnet by constant shaking

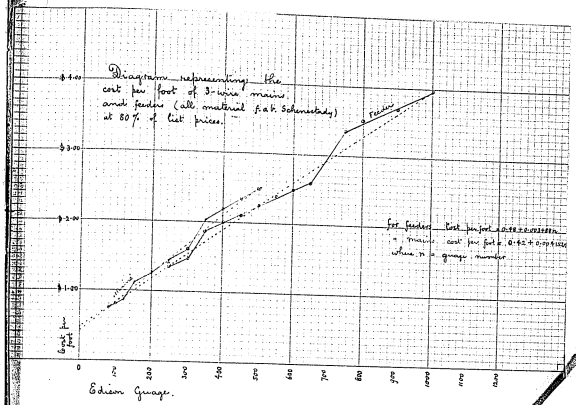


Diagram representing the cost per foot of 3-wire mains and feeders (all material f.o.b. Schenectady) at 80% of list prices.
$4.00
$3.00
$2.00
$1.00
Cost per foot
Feeders
For feeders cost per foot = 0.08 + 0.0000[illegible]
" mains cost per foot = 0.62 + 0.0[illegible]
where n = gauge number
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Edison Gauge.

Calculation of the most economical distance for Feeding points in circular Distribution.

The accompanying diagram shews that to a fair degree of approximation, the cost of feeder or main per foot as bought but not layed is of the form $\alpha + \beta d^2$, where α and β are constants and d is the diameter of the conductor (outside) in mils.

For feeders cost per foot \$ $= 0.48 + 3.488 \times 10^{-6} d^2$

" mains " " " $= 0.42 + 4.152 \times 10^{-6} d^2$

The cost of laying, including trenching, jointing and testing may be estimated as another constant δ, it will be greater for larger tubes but where there are larger tubes there will be generally more in one trench so that δ may be regarded as constant per foot.

Now consider a system whose mains are a series of concentric circles. We will assume that these circles are cross connected by radial mains whose number shall be independent of the number of feeders we employ, and also that all the feeders shall be tree nodal, not subdivided, as is now so customary.

Then let R be the radius of the supply circle (in feet)

m . . permissable drop in the mains (volts)

f . . . . . feeders (volts)

I . . total current on one outside conductor supplied by the feeder or feeders (amperes)

ρ . . resistivity of copper per cubic foot at ordy. temp. in ohms.

d . . diameter of the outside conductors

n . . number of feeders employed, at uniform distances apart

c . . cost per foot of layed conductor

C . . total cost . . .

Then with n feeders

$$\frac{I}{2n} \cdot \frac{2\pi R}{+n} \cdot \frac{4\rho}{\pi d_m^2} = m$$

$$\therefore d_m^2 = \frac{RI\rho}{mn^2}$$

$$c_m = \delta_m + \alpha_m + \beta_m \cdot \frac{RI\rho}{mn^2}$$

$$C_m = 2\pi R\left(\delta_m + \alpha_m + \beta_m \frac{RI\rho}{mn^2}\right)$$

Also with n feeders

$$\frac{I}{n} \cdot R \cdot \frac{4\rho}{\pi d_f^2} = f$$

$$d_f^2 = \frac{4IR\rho}{\pi n f}$$

$$c_f = \delta_f + \alpha_f + \beta_f \frac{4RI\rho}{\pi f n}$$

$$C_f = nR\left(\delta_f + \alpha_f + \beta_f \frac{4RI\rho}{\pi f n}\right)$$

$$C_m + C_f = R\left\{2\pi\left(\delta_m + \alpha_m + \beta_m \frac{RI\rho}{mn^2}\right) + n\left(\delta_f + \alpha_f + \beta_f \frac{4RI\rho}{\pi f n}\right)\right\}$$

$$\frac{dC_{m+f}}{dn} = R\left\{\frac{2\pi\beta_m RI\rho}{m} \cdot \frac{-2}{n^3} + \delta_f + \alpha_f\right\}$$

for min: $\delta_f + \alpha_f = \dfrac{4\pi\beta_m RI\rho}{mn^3}$

or $n = \sqrt[3]{\dfrac{4\pi\beta_m RI\rho}{m(\delta_f + \alpha_f)}}$

and $\dfrac{2\pi R}{n} = \dfrac{2\pi R}{\sqrt[3]{\dfrac{\beta_m RI\rho}{2\pi^2 m(\delta_f + \alpha_f)}}}$ = economic distance.

$$= \sqrt[3]{\frac{R^2}{I}} \times \sqrt[3]{\frac{\beta_m \rho}{2\pi^2 m(\delta_f + \alpha_f)}}$$

$$\text{i.e.} = \sqrt[3]{\frac{R^2}{I}} \times 90$$

If $\beta_m = 4.152 \times 10^{-6}$ $\rho = 10$

$\pi^2 = 10$ $m = 1$ $(\delta_f + \alpha_f) = 1$

It appears that δ_f is nearly constant and $\neq 3000$

$\therefore x = 1150$.

Trial of a small Perret Motor, sent to the Laboratory for the Manufacturing Co. to be tested on a Polarude-Edison Battery. 22nd Feby. 91.

Res: of this series wound motor Field. 0.129 Armature 0.185 } Total. 0.318

Worked on 8 cells of battery (battery that have been set up about two months). E.M.F 5·8 v. after work. P.D. on motor 4.0 Current averages 3·687 = 14·6 watts in motor $\frac{1}{20}$th HP. Speed of fan about 1260 rpm. Test satisfactory. Res: of battery, blue leads + galvo $\frac{5.8-4.0}{2.65} = 0.5\Omega$ or 0·0625 ω per cell.

With 6 cells p.d. 3·1 v. 0.68 amp. (0·192) 1000 rpm. = 3·47
" 4 cells 2·1 0·47 660 " = 2·57.

∴ Magnetic Test of ¼ HP Motor 14th February 1891.

No. of Wks.	E.M.F.	Bonds.	a	Mean thro'	No. of turns	q. per div.	
1	1·43147	19	1.43147×10^{-7}	125·0	14	1.148×10^{-9}	

Tn. of Wk.	Observ.	Amp.	Amp turns	MMF	No. of turns	Mean	φ	B	ρ	Winding	
1	0·042	0·219			3	60				5 turns	
2	0·092	0·428			2	128				round	
3	0·170	0·887			2	215				full	
4	0·320	1·669			2	317·5				center	
5	0·588	3·067			2	400					
6	0·042	0·219			2	65					
7	0·092	0·428			2	107·5				10 turns	
8	0·170	0·887			2	183				round	
9	0·320	1·669			2	253				knees	
10	0·588	3·067			2	295·5					
11	0·042	0·219			2	23·5					
12	0·092	0·428			3	47				5 turns	
13	0·170	0·887			2	76·5				round	
14	0·320	1·669			3	100				armature	
15	0·588	3·067			2	112				4 turns	
16	0·588	3·067			1	112				5 turns below.	

DATA [illegible] EDISON % GRADE STREET CAR MOTOR. 2 [illegible]

Type [illegible] Gramme Ring

Work. To pull a street-car weighing 20,000 lbs. up [illegible] grade at the rate of 4 miles per hour [illegible] overload.

Equivalent Pull at axle 1350 lbs. weight.

Velocity ratio of armature and car-wheel shafts 5.

Torque needed at full load 338 ft-lbs. on armature shaft.

Power exerted in driving car at full load 12 kwts. [illegible] 16 HP.

Allowing 0.[illegible] efficiency, 17.1 kwts. or 23 HP. absorbed.

Voltage at terminals assumed 500, amperes in arm. [illegible] load 34.3

Diameter of armature over all 22" Speed, 2[illegible]0 to [illegible]00 rpm.

Peripheral velocity 1200' to 5320' per min.

Armature Dimensions, Diameter over all [illegible]
" conductors [illegible]
" body insulation [illegible]
" armature bod[illegible] [illegible]
under armature bod[illegible] [illegible]

Bore of poles diameter [illegible]

Breadth of armature, above [illegible]
[illegible]
[illegible]

Cross section of armature [illegible]

Estimated weight of [illegible]

Armature wire [illegible] B&S. 0.0[illegible] [illegible]

~~[illegible]~~ [illegible]

Commutator 200 divisions [illegible]
to the commutator. [illegible]

Fibre divisions [illegible] extend
[illegible] of [illegible] Thickness of fibre [illegible]

Total length of [illegible] on armature [illegible]

Total weight of wire on armature [illegible] lbs.

Area of [illegible] mils. [illegible]

Res. of armature between brushes [illegible]
one [illegible] [illegible]

[illegible] at full load, [illegible]

[illegible] in armature at full load, [illegible]

[illegible] brushes four in number, each double.

[illegible] on armature [illegible]
in [illegible] operation of [illegible] armature [illegible]

"[illegible] connections, [illegible] B&S. 0.[illegible]" insulated [illegible]
[illegible] inches each length. This size of wire [illegible]
[illegible] of winding.

[illegible] and magnets of ordinary cast iron [illegible]
[illegible] length 1[illegible]", interflange 10.[illegible]" [illegible]
1[illegible] for each core, [illegible] lbs. in all.

Winding [illegible] field. All four [illegible] spools in series.
[illegible] lbs. of #[illegible] magnet wire for each core, in about [illegible]
layers of [illegible] turns each. Resistance of each spool [illegible]
[illegible] of wire in each spool [illegible] Diam. [illegible]

Total weight of copper on field [illegible] sheet, 312 lbs.

Current in field at full strength ([illegible] hot), 2.0 amperes.

Energy [illegible] field [illegible] watts.

Determination of the winding for a 6% grade Edison Motor
2nd March 1891. Basis — quadripolar, gramme-ring armature, to pull a 20,000 lb car up a 6% grade, at slow speed — 4 miles per hour, on full load.

Pull = 12.00 + 10 × 15 = 1350 lbs wt. at axle 30" diam car wheel = 1688 ft lbs

Velocity ratio 5" = 337.6 ft×lbs at armature at full load.

Speed 250 to 750 rpm of armature = 50 to 150 rpm of car wheels = 4.66 to 13.4 miles per hour

Power exerted usefully is $1350 \times \frac{22}{15} \times \frac{4.66}{737}$ = 12 horse 16 HP.

Allowing an efficiency of 0.7 = 17.14 horse = 22.55 HP = 34.3 amp @ 500 v.

Diameter of armature 29" over all circ: 91.12" = 7.6'

Peripheral velocity 1900' per min @ 250 rpm, and 5700' per min @ 750 rpm

Flux useful flux through armature 2,400,000 lines and will v. 1.5
Total flux . ores 3,600,000

Density in armature space 8000 . square cm. of lines per sq. cm.
. . . of field magnets 7500 cast iron
. . . Keepers . . 7500 .

Armature Dimensions. External diameter 29.0" over all 91.1 — 73.60 — 234
Binding wire 0.09" — 0.23
Diameter over conductors 28.82" — 90.54 — 73.2 — 230.0
Diameter . body inside 28.10" — 88.28 — 71.4 — 224.2
. . wire body 27.90" — 87.66 — 70.9 — 222.6
Internal . . 21.25" — 66.74 — 53.7 — 168.6
Breadth mean of core 7" — 17.8
External breadth 7½" — 18.4
Internal . 6⅞" — 17.2

Area of external circle of armature body 615.75 sq. in. } area of annulus 271.25 sq. in.
. . internal . . . . 354.5 . . } 1750 sq. cm.

Cross-section of armature core 23.625 sq. in 152.4 sq. cm.
Volume . . . 6820.7 c. in. 111,800 c. c.

Sp. g. 5.3 = 1,588,000 gms = 158.8 kgms = 350 lbs.

Polar bore diameter 29.375" circ: 92.25" cm = 74.6 and 234.4 circ

Wire 5×10" ÷ 4.167 × 2.4×10⁶ = 5×10³ = 5000 wire all round.
5 layers of 1000 each. Space per wire on cat: circ 0.0933
Diameter of covered wire 0.071" d.c. = 0.058" = # 17 B.W.G. = 3364 cmil
Armature body insulation, 0.1". Clearance 3/16". Entefer 1.85 cm.

Mean turn = 23" = 1.915' and total length = 9590' = 97.8 lbs.

Res: 29.42 v. cold = 33.65 ohms (60°c) = 39.52 v. hot @ 100°c.

Res: between brushes without platinoid connecting wires, and assuming contact on single bar 1.84 v. cold, 2.10 @ 60°, 2.47 v @ 100°c.

Drop at full load (34.3 amp) 63.1 v . 72.0 . . 84.7 . .

Energy spent in armature at full load of 34.3 amp 2160 watts. 2470 watts. 2905 watts.

Torque at full load, assuming full flux thro armature per ampere
5,000 × 2.24 × 10⁶ × 10⁻⁸/6.283 = 1.91 × 10⁶ dynes = 1.95 × 10² kgms wt @ 1m
= 5.28 kgms per amp at periphery armature = 11.64 lbs per ampere.
= 399 lbs. at full load of 34.3 amp = torque of 6690 cm kgms = 484 ft lbs

Cores and Keepers of cast iron 9.75" (24.76) diam = 74.66 sq. in 481.7 sq. cm
Length 11". Inter flange 10.5" = 26.67 cm Thickness of copper = 3/16" = 0.476 cm
Diam: over copper 10.125". Weight of copper 11 × 31.4 × 3/16 × 0.323 = 20.9 lbs
= 84 lbs of sheet copper on all four spools. Internal winding diameter 10.5".

Magnetic circuit.

			$\frac{l}{A}$	$\frac{l}{A}\mu$	μ	r
Armature length	$\frac{40}{\pi}$ cms	Cross section ·252	0.0674	8000	0.001	0.000016
Cores	"	100	480/2	0.417	7500	0.01	0.004.17
Entrefer		1.85×2	888/2	0.00833	1.0	0.00833
Cast iron cores		22×2	300/2	0.3		0.01	0.003
							0.01710

To force 13200 000 lines through this circuit

$1.257\ AT = 1.2\times10^6 \times 1.7\times10^{-2} = 2.04\times10^4$

$AT = 16,230$ or 8120 per spool.

The surface of each spool is about $26.67 \times 14\times2.5\times3.14 = 2930$ sq. cm. Allowing 15 sq. cms per watt = 195.5 Watts per spool, or 20 sq. cms per Watt 146.5 say 250 Watts. = 1000 Watts in field at slowest speed. 2.0 amp. @ 500 volts all in series. = 4.060 turns per spool to have a res. of 62.5 ω that the mean turn = 3.25' and the total length 13200' for 62.5 ω or 211.2 feet per ω @ 60°C = either # 18 B.W.G. 0.049" or # 16 B.S. 0.051". 68.4 ω and 60.4 ω respectively. The weight = 106.8 lbs. or 92.4 lbs respectively: say the former = 427 lbs. in all. Making total weight of copper on the field 511 lbs. The space occupied = 593 c.in. per spool an ext. diam. over wire of 13.5" or over insp. 14.0".

Mean diam. 12" mean circ. 3.14'. Wire 0.051" s.c.c. to 0.060" = 170 turns per layer × 25 layers = 4250 turns.

Energy absorbed at full load. fields. 2.0 amp 1000 watts.
armature 34.3. 17150
Total 18,150

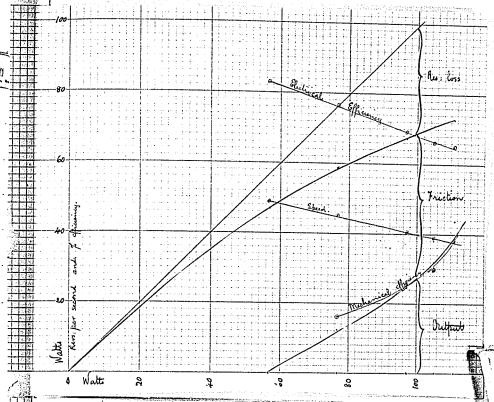
Probable delivery on 6% grade 0.75 × 17150 = 12,860 = 48 amp.

Determination of the winding for the ½ H.P. motor at 250 volts

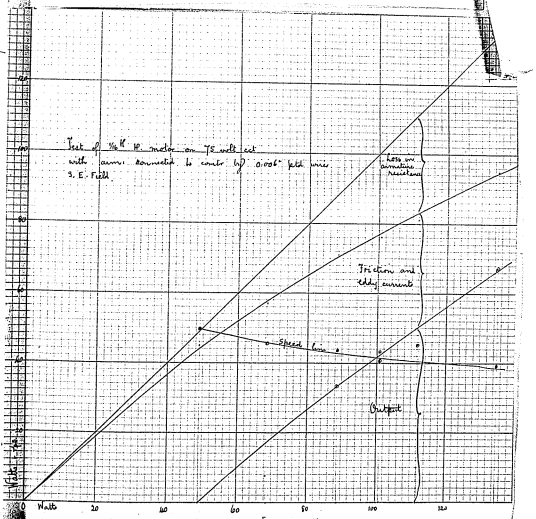
The grooves in the 120 volt armatures are 0.225" × 0.225". Keeping the same depth, we have 0.21" for winding. There are 49 turns in the 120-volt grooves and 90 may be allowed in the 240 volt grooves or 9 layers of 10 wires each. 0.21 ÷ 9 = 0.0233" and bare diam. = 0.0114" allowing 0.009" for insulation = # 28 B.W.G. d.c.c. There will be about 1800' of this wire @ 0.0603 ω per foot @ 60°C = 108 ω or 27 ω in the armature without including platinid wire. The breadth will be 10 × 0.0233" = 0.233" + 0.025" = 0.258" say 0.26" wide.

The field should be series wound, and not more than 5 ω res. @ 60°C, so that at full load the energy may not exceed 50 watts in it. The mean diam. of the coil will be about 0.75' so that with 1000 turns there will be 750' = 150' per ohm @ 60°C. = 0.042" # 19 B.W.G. s.c.c. 50 of this wire @ 0.8 lbs. per ω = 4 lbs. of wire

No of Obs	Block	P.D. at motor terms	Amperes in armat. ct	Energy absorbed watts	Res. of armat.	Drop in armat.	E.M.F. of armat.	Speed of armat. r.p.m.	r.p.s.	E.M.F. per armat. per sec.	Energy lost in
1	0·148	73·5	0·772	56·7	16·5ω	12·7	60·8	2925	48·75	1·247	9·8
2	0·200	73·5	1·043	76·7		17·2	56·3	2725	45·42	1·24	25·2
3	0·258	72·2	1·346	97·2		22·2	50·	2433	40·55	1·233	31·9
4	0·295	72·2	1·486	107·3		24·5	47·7	2325	38·75	1·231	36·4
5	0·300	72·2	1·565	113·0		25·8	46·4	2290	38·17	1·216	46·4
6	0·288	72·2	1·502	108·5		24·8	47·4	2290	38·17	1·242	37·3



No. of Obs	P.D. at M.T.	Block	Amperes in armat.	Resistance in armat. armature	Drop in armat.	Activity in heating w.	E.M.F. in armat.	Speed r.p.m.	r.p.s.	E.M.F. per sec. per sec.	Effort
1	76·5	0·123	0·641	49·0	6·74	4·3	69·8				44·7
2	77·2	0·17	0·886	68·4	12·18	10·8	65·0	2980	49·67	1·308	57·6
3	·	0·222	1·157	89·3	15·9	18·4	61·3	2745	45·75	1·340	70·9
4	76	0·251	1·309	101·1	18·0	25·2	58·0	2630	43·83	1·324	75·9
5	75·8	0·278	1·449	111·9	19·9	30·9	55·9	2600	43·33	1·290	81·0
6	75·3	0·334	1·752	135·3	24·1	40·5	54·1	2365	39·42	1·372	94·8



Determination of the field winding for 120 watt circuit.
The current at which the motor will deliver 50 watts at 75 volts on armature terminal is 1·57 ⅄. This current must produce a drop of 40 volts = 26·7ω res. #24 B.W.G. 0·022" has a res. of 16·63ω per ft. ∴ 60·0 = 1·6 ft.
The current at which the motor will drive the fan at 11·40 r.p.m. is 1·40 volts is 0·5 amp. so that the drop for 0·8 ⅄ is 75 volts = 150 ω. ∴ 120 ft
#28 B.W.G. q.s. wire has 1·074 ω per foot = 125 feet.

Test of 1/16 h. P. motor 9th March 1891. Solid pole pieces

Since the last test recorded on page 90, the platinoid connecting wire have been reduced to 0.00145 and the pole pieces have been made solid instead of laminated. The motor was floated, and separately excited

Balance	Moment	6165 Moment	Delivery Watts	Effort	Friction	Mech. eff.	Elect. eff.		
50 @ 0	-	-	-	45.9	46.9		0.827		
50 @ 18.7	435	2683	12.2	58.7	46.5	0.159	0.766		
50 @ 19.8	978	6.012	24.4	67.3	42.9	0.251	0.692		
50 @ 26.8	1340	8.262	32.0	70.9	38.9	0.298	0.661		
50 @ 37.3	1865	11.50	43.9	72.6	28.7	0.389	0.643		
50 @ 37.3	1865	11.50	43.9	71.2	27.3	0.405	0.656		

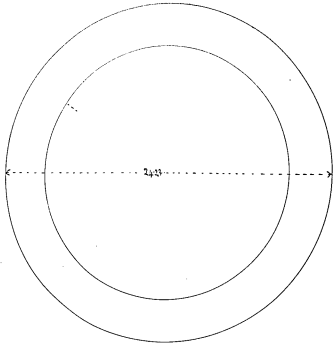
Second test of 1/16 HP. on 75 volts ext: Field separately excited, after replacing the platinoid wire with a larger size 0.0066. Res: of armature 13.75 ohm 3.25 between adjacent bars. No sparking

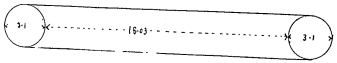
Motor driving C.C. 1/8 HP. model as dynamo with S.E.F.

Balance	Moment	6165 moment	Delivery watts	Friction	Mech. eff.	Electrical eff.	Amp. in on field	Load	
				44.7		0.913	2240	Lifts	
50 @ 5	250	1.54	7.65	50.	0.1148	0.842		1/8 C.C	
50 @ 24.0	1200	7.398	33.85	27.	0.379	0.794		S.E.F.	
50 @ 29.7	1485	9.155	40.12	35.8	0.297	0.763		3 lamp	
50 @ 33.7	1685	10.39	45.02	36.	0.402	0.737		2 "	
{50 @ 25.3 / 100 @ 15.}	2765	17.05	67.2	27.6	0.497	0.718		1 "	

When separated with its fan; on 76.5 volts the armature and fan made 2900 r.p.m. @ 76.5 v. + 0.165 Ohms 0.86 = 66 watts
" 1440 " @ 40.0 " " 0.095 " 0.495 = 19 watts

Plan and diametral section of ring half size
Syracuse cast Steel





Mean diameter of ring 21·13
" circumference . . 66·4

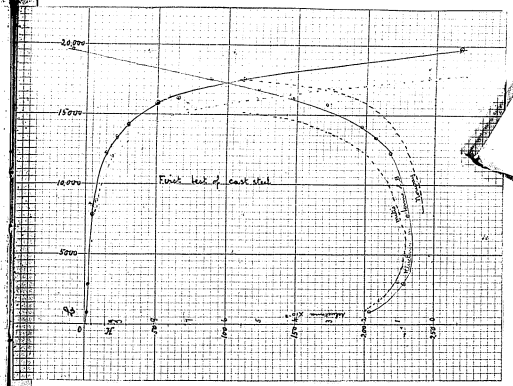
Analysis of this steel by two independent firms :-

Syracuse analysis

C 0·25 to 0·3 %
Mn 0·3 . 0·4
Si 0·15

Stratton analysis

C 0·25 %
Mn 0·36
Si 0·15
Ph 0·118
S 0·064



Test of the magnetic permeance of a ring of soft steel received from Schenectady March 5th

The winding and dimensions of this ring were all repeated after reception. The primary consists of 690 turns of #16 B.W.G. and the secondary 100 turns of #25 B.W.G. inside the primary.

No. of Obs.	Source of EMF	Condr.	EMF	Q	No. of Turns	Mean throw	per div.		
	1 c.c.	1 $\times 10^{-15}$	1.43147 $\times 10^{8}$	1.43147 $\times 10^{-7}$	13	166.63	1.23×10^{-9}		

No. of Obs.	Obsvd.	Amp.	MMF.	No. of Turns	Mean throw	Perm. in Lat.	Perm. of cat.	Φ	φ	L	$\frac{\varphi}{L}$
1	0.022	0.1147	14.97	7	33.1	25000	39,250	4.09×10^{-7}	6.158×10^{3}	816	1.935
2	0.035	0.1825	2.382	7	118.4	25,000	30,250	1.456×10^{-7}	2.202×10^{3}	2,917	0.816
3	0.096	0.449	5.862	7	172.5	50,000	55,250	2.122 "	5.862×10^{3}	7766	0.755
4	0.22	1.147	14.97	5	141.4	100,000	105,250	1.739 "	9.151 -	12,120	1.239
5	0.322	1.680	21.93	5	155.0	-	-	1.907 "	18.04 -	13,200	1.649
6	0.441	2.30	30.03	5	166.5	-	-	2.036 "	30.71 -	14,190	2.116
7	0.713	3.72	48.57	5	180.9	-	-	2.225 "	11.84 -	15,690	3.095
8	0.970	5.06	66.06	5	187.8	-	-	2.310 "	12.15 -	16,100	4.103
9	1.650	8.61	112.4	5	204	-	-	2.509 "	13.21 -	17,500	6.423
10	3.92	20.45	267.0	3	230	-	-	2.829 "	14.89 -	19,730	10.37

Internal diameter of ring 18.03 cm External diameter 24.27 Mean 21.15
" circ. 56.64 " 76.24 66.44
Cross diameter 3.1
" circ. 9.738
" area 7.548 sq. cm
Weight of ring in air 8 lbs. 10 oz 150 grains = 13807 150 grs. = 3912 + 9.7.
= 3921.7 grs.
" " " water
Volume of ring from measurements of diameter 501.5 c.c.
Sp. gr. of metal 7.82
1.257 × 8.7 × 690/66.44

On braiding german-silver wire with a view to increasing its carrying capacity. Mar. 11 & 31.

A sample of g.s. wire has a diameter of 0.005" (0.0127) a resistance per cm: of 0.3084 ω per cm: @ 18° C, and a surface per cm: of 0.0399 sq cm. It reached dull redness in air with a current of 1.337 and an activity per cm of 0.709 w. say or 1.77 watts per sq. cm.

When 16 of these wire are braided together, the resulting diameter is 0.031" (0.0787) the resistance per cm: 0.0239 ω instead of 0.3084/16 = 0.01928 ω and the surface per cm is for a round wire of equal diameter 0.24674 sq cm. The current that heats this to visible redness is 1.40/0.1918 = 7.3 amp: an activity of 1.273 watts per cm: or 5.15 watts per sq. cm.

When one wire of equal gross section to these 16 combined, namely #25 B.W.G. 0.020" was tried, its resistance per cm: was 0.01444 ω, and the current required to heat it to dull redness was 7.51 amp, the diam: being 0.0501 the cm: is 0.1596 sq. cm, and the surface 0.1596 sq. cm: per cm:. The activity per cm: would be about 1.08 watts and per sq. cm: about 6.77 watts.

When one wire of nearly equal resistance to that of the braid per unit of length namely #26 B.W.G. 0.0288 ω per cm. the diameter was 0.0165" and the current required to bring it to dull redness 5.427

No. of Obs.	Diam. of wire	Area	Circumf.	Surface per cm.	Res. per cm. @ 18°C	Current needed to make dull red	Activity needed per cm. watts	Activity per sq. cm.		
1	0.005" 0.0127	1.2668×10^{-4}	0.0399	0.0399	0.3084 ω	1.33	0.709	1.77	single wire	
2	0.031" 0.0787	4.864×10^{-3}	0.2474	0.2474	0.0239	7.3	1.273	5.15	braid	
3	0.020" 0.0508	2.027×10^{-3}	0.1596	0.1596	0.01444	7.51	1.08	6.77	single wire	
4	0.0165"				0.0288	5.42			" "	
5										

On the energy lost in an iron wire armature by eddy currents in the insulated iron wire.

Let R be the radius of the wire supposed insulated.
Also assume that the magnetic flux is parallel to the axis of every wire and uniformly distributed among them.
Then consider the cross section of the armature of breadth B and depth D, made up of insulated round iron wires.
Take any one wire and a length δl of it. The lines of eddy flow will be concentric circles. Let $\dot{\mathcal{E}}$ be the time rate of flux variation, then in an elementary cylinder of radii r and $r+\delta r$, the instantaneous E.M.F. will be $\pi r^2 \dot{\mathcal{E}}$
" resistance will be $\rho 2\pi r / \delta l \, \delta r$
" instantaneous current $\dfrac{\pi r^2 \dot{\mathcal{E}} \, \delta l \, \delta r}{2\pi r \rho} = \dfrac{r \dot{\mathcal{E}} \, \delta l \, \delta r}{2\rho}$
" " activity $= \dfrac{\pi r^3 \dot{\mathcal{E}}^2 \, \delta l \, \delta r}{2\rho}$

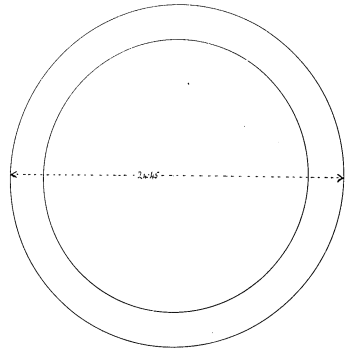
Integrating this expression from $r = 0$ to $r = R$

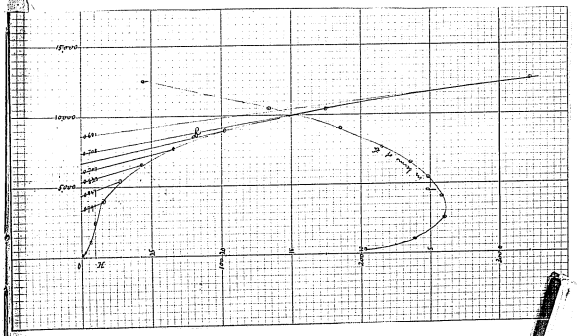
activity in δl of the wire $= \dfrac{\pi \dot{\mathcal{E}}^2 \delta l}{2\rho} \int_0^R r^3 \delta r = \dfrac{\pi \dot{\mathcal{E}}^2 \delta l R^4}{2\rho \cdot 4} = \dfrac{\pi R^4 \dot{\mathcal{E}}^2 \delta l}{8\rho}$

In the section of the armature BD, there will be $\dfrac{BD}{R^2}$ wires so that the activity in the whole armature of length δl is $\dfrac{\delta \pi R^4 \dot{\mathcal{E}}^2 l}{8\rho}$
$= \dfrac{SA \dot{\mathcal{E}}^2 \delta l}{8\rho}$ where S is the cross section of the armature and A is the area of the wire.

The total activity in the entire armature will be $= \dfrac{SA}{8\rho} \int_0^l \dot{\mathcal{E}}^2 \delta l$
in which $\dot{\mathcal{E}}$ must be expressed as a known function of l.

Plan and diametral section of soft iron ring half linear dimensions





Magnetic Test of a ring of iron received from the Engineering Department and marked "soft iron" 11th Mar. 91.

The ring was wound with two secondary coils each of 50 turns and on opposite sides. Outside this there were 275 turns on the first layer and 262 turns on the second layer, 237 turns on the third layer making 774 turns in all.

No. of Obs.	Obsd.	Amp. in	H in MKS	B in $\frac{L}{\pi}$	No. of turns	Mean throw (1st turns)	Resp. in cal.	R. of G. cal.	q	φ	$\mathfrak{B}$	μ
1	0.0225	0.1173	1.65	14.13	5	10.2		2.250	1.259×10^{-6}	6.614	132.5	$\times 10^{-7}$ 12.45
2	0.0350	0.1825	2.58		5	20.6 8		-	2.542 -	13.35	267.6	9.614
3	0.0490	0.1640	6.55		5	83.6 26		-	1.032×10^{-7}	54.17	1086.0	6.315
4	0.1375	0.717	10.13		5	199.4 25		-	2.35 -	123.40	2474	4.994
5	0.2305	1.202	16.98		5	53.1 8	25.000	30.250	6.552×10^{-7}	19.820	3974	4.272 3376
6	0.380	1.982	27.99		5	72.4 10	-	-	8.934 -	27.030	5419	5.164 4371
7	0.575	2.999	42.36		5	87.3 16	"	-	1.077×10^{-6}	32.580	6532	6.483 5537
8	0.8875	4.629	65.36		5	102.8 22	"	-	1.268 -	38.360	7690	8.498 6610
9	1.390	7.248	102.4		5	118.9 20	"	-	1.467 -	44.380	8896	11.51 6654
10	2.36	12.31	173.8		3	140 21	"	-	1.727 -	52.240	10470	16.60 7000
11	2.36	22.74	321.2		3	167.5 25	"	-	2.067 -	62.520	12530	25.63 8432

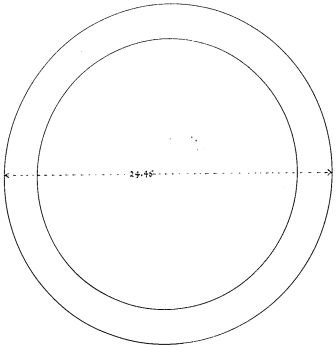
E.M.F	EMF	Capacity	q.	Mean throw	q. per div.
1 Gb @ 21°	volts 1.43314	1 μ	1.4314×10^{-6}	116.0	1.234×10^{-7}

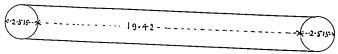
Cross sectional diameter of ring 2.52 cms
- area - 4.9876 sq. cms.

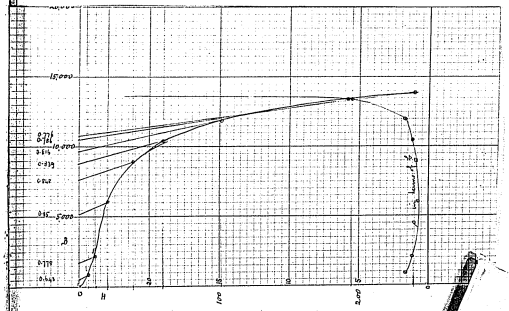
External diameter of ring 24.45
Internal - - - 19.41
Mean - - - 21.93
- circumference - - 68.9 cms.
Volume of ring 343.6 c.c.

Mass of ring in air 5 lb 6 oz 470 grs. = 2469.4 grms
- water 4 - 11 oz 400 - = 2152 -
Volume of ring 317.4 c.c.
Sp. g. by dimensional volume 7.19
- - weights - 7.78

Plan and diametral section of ring half linear dimensions







Magnetic Test of a ring of iron received from the Engineering Department and marked "cast steel" from the Eureka Cast Steel Co. Lamokin Chester Pa.

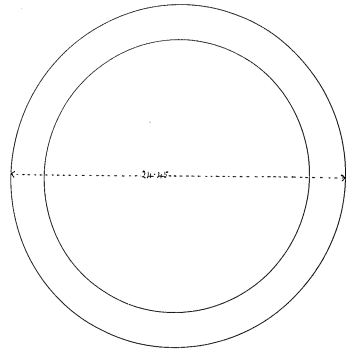
The ring was wound with 100 turns of secondary wire in two coils and opposite situated, and above these, with 280 turns of coarse primary wire in two layers.

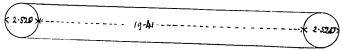
No. of turns	Source of EMF	EMF	Mean Thrust	Quantity	q per div.
16	1 G.C. @ 21°C	1.4314	115.5	1.4314×10^{-7}	1.239×10^{-3}

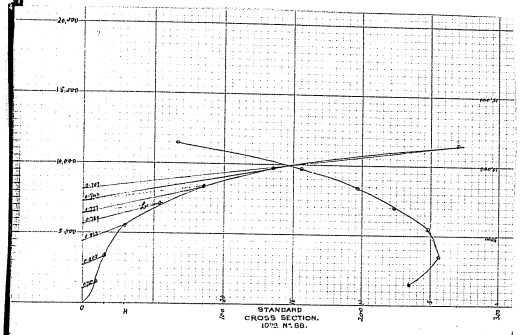
No. of Ob.	Hook	Amp'ge	MMF	H	No. of turns	Mean Thrust (20 turns)	Rev. in cell	A. of G. cell	q	φ	$\frac{\varphi}{H}$ μ
			352	5.106							
1	0.244	1.272		6.5	1806 / 278	616	0	5250	7632×10^{-7}	4,005	1.623×10^{-7}
2	0.469	2.446		12.5	8198 / 1711	1678	0	-	2079	10,920	1.145
3	0.766	3.994		20.4	16038 / 5153	880	25,000	30,250	992	29,990	0.680
4	1.422	7.508		38.34	29928 / 7070	1183	-	-	1466	44,350	0.864
5	2.256	11.76		60.05	40480 / 7940	1390	-	-	1722	52,090	1.153
6	3.802	19.83		101.3	51840 / 9660	1577	-	-	1945	58,830	1.722
7	7.330	38.21		195.1	73370 / 13,810	1772	-	-	2195	66,400	3.754
8	9.00	46.93		239.7	93810 / 16,720	1831	-	-	2267	68,580	24.95

The mean diameter of ring's cross section = 2.515 cms.
- area - - - = 4.968 sq. cms
external diameter . . = 24.45 cms
internal - - - = 19.42 -
mean - . . = 21.935 -
" circumference " " = 68.92 -
— volume of ring from dimensions = 342.4 c.c.
weight in air 86 of 960 grs. = 2500 grs
- water 76 - - - = 2.155 -
volume of ring from weights = 345 c.c.
sp. g. from dimensional volume = 7.302
- - - weighing . = 7.2444
Mean sp. g. = 7.273

Plan and Diametral Section of ring half linear dimensions







Magnetic test of a ring of iron received from the Engineering Department and marked "Hard Iron" from James Moore, Brick Hill Iron Works, and 16th Buttonwood St Phila. P.

The ring was wound with 100 turns of secondary wire in two opposite coils, and above this 398 turns of primary wire in two layers.

No. of Obs.	Batch	Amp.	MMF	H	No. of Turns	Mean Turns	Res. in Ext.	Run of ext.	γ	φ	$\mathcal{B}$	ρ	$\mathcal{B}_{max}$
			50.94	72.62		50 turns							
1	0.232	1.21		9.164	5	115.8 / 23	0	5250	1.423×10^{-8}	7530	1,510	6.07×10^{-4}	1890 0.75
2	0.390	2.034		14.77	4	144.6 / 37	25,000	30,250	5.526×10^{-8}	14,710	3,350	4.44	2690 0.80
3	0.778	4.058		29.47	5	73.4 / 13.7	-	-	9.095 -	27,510	5,516	5.34 -	4486 0.83
4	1.432	7.466		54.22	5	95.3 / 20.1	-	-	1.181×10^{-7}	35,720	7,162	7.57 -	5862 0.79
5	2.255	11.76		85.40	5	110.9 / 26.1	-	-	1.374 "	41,560	8,332	10.25 -	6932 0.77
6	3.70	19.29		140.1	3	129.6 / 35.5	-	-	1.606 "	48,580	9,740	14.39 -	7944 0.82
7	7.12	37.13		269.6	3	153.3 / 45.0	-	-	1.899 "	57,450	11,520	23.40	8988 0.77

For the condenser constant of this and the following test see that given on the preceding page, which applies to these measurements.

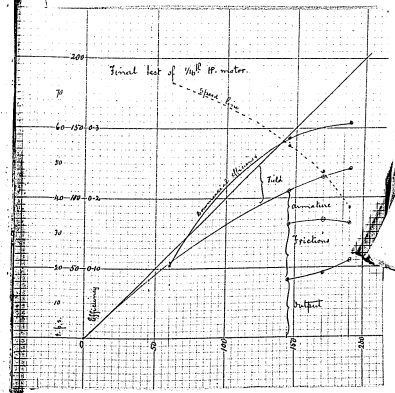
Mean diameter of cross-section of ring 2.52 cms.
" area - - - - - 4.988 sq. cms.
" external diameter - - 24.45 cms
" internal - - - 19.41 -
" — - - - 21.93 -
" — circumference - - 68.9 -
Volume of ring from dimensions 343.7 c.c.
Weight of ring in air 6 lbs 1 oz 2502 gms
" - - water 75 200 2145 gms
Volume - - from weights 357 -
Sp. g. of ring from dimensions 7.28 -
" weights 7.01
Mean 7.145

Repetition of test of Soft Cast steel ring from Schenectady.

The ring was wound with 100 turns of secondary wire in two opposite coils, and this was overlaid with 329 turns of primary wire in two layers. For the first test of this ring see p. 103.

No. of Obs.	Batch	Amp.	MMF	H	No. of Turns	Mean Turns	Res. in ext.	Run of ext.	γ	φ	$\mathcal{B}$	ρ	$\mathcal{B}_{max}$
1	0.237	1.236		7.694	5	169.6 / 32	25,000	30,250	2.102×10^{-8}	63,580	9,776	0.88	7,566 0.82
2	0.566	2.951		18.37	6	243.6 / 42	-	-	3.019 -	91,320	12,600	1.458 -	10,430 0.828
3	2.238	11.67		72.64	5	166.9 / 32	50,000	55,250	2.067 -	114,200	16,700	4.61 -	13,200 0.794
4	3.77	19.65		122.3	5	177.6 / 32.5	-	-	2.201 -	121,600	16,780	7.29 -	13,470 0.793
5	7.55	39.36		245.0	3	194 / 31.3	-	-	2.404 -	132,800	18,350	13.37 -	13,880 0.755

P.D. on motor	Oberh.	Current Ohmmeter	Activity in motor	Amperes in mains	Watts	Drop in field	Energy in field	Energy in armat.	Drop in armat.	Energy spent in armat.	Effect	Speed r.p.m.
121.0	0.072	0.375	45.4	1125	1414	10.46	3.9	21.0	5.8	2.2	19.8	2520
121.0	0.095	0.496	60.0	1488	1870	13.84	6.9	17.2	7.6	3.8	13.4	1705
124.90	0.230	1.20	145.2	3600	4520	33.5	40.2	105.0	18.5	22.2	82.8	3325
120.75	0.270	1.405	170.1	4224	5308	39.3	55.3	184.8	21.7	30.5	84.3	2865
120.25	0.303	1.580	190.0	4740	5957	44.1	69.7	120.3	24.3	38.4	81.9	2210
120.0	0.295	1.538	184.6	4614	5800	42.97	166.0	118.6	23.7	36.5	82.1	2215



Magnetic Test of #2 D.C. Edison Motor 13. E. 91.

Two turns of wire were taken round the base of the magnets. 1st on the end where the iron idler frame projects about 4", and 2nd on the end - - - - - - only. 2".

No. of Ov.	Ohmch	Current in field	Time round magnet	No. of throws	Mean throw	∫ for 1 sec	Q	R in cct	R. of cct	φ	B	ν
1	0.314	1.773	5	4	174	1.234×10^{8}	2.156×10^{8}	108,000	110,250	4.524×10^{5}	10,560	1.26
2	-	-	5	4	173	-	2.144×10^{8}	-	-	4.514 -	10,500	

At this strength of current in the fields 21 % of the flux is lost in leakage.

Efficiency test of the 1/16 th H.P. motor before sending it to New York.

The motor was mounted in the dynamometer self exciting and coupled to the 1/8th. H.P. c.c. with the following results.

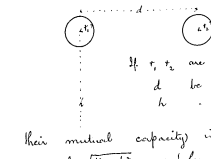
	Emf Sheet Tp.	Emf for 100 per sec.	Balance Stops	Ω	Moment	Lbs moment	Delivery watts	Friction	Electrical efficiency	Commercial efficiency	Load	Volts on mains
0	100 42.0	0.95						18.1	0		disc.	117
5	172 29.75	1.25	50	7.0	350	2.158×10^{5}	6.42	7.0		0.107	Aqu. light	112
25	190 35.4	1.25	"	24.5	1225	7.55 "	41.8	41.0		0.287	S.E.F	90.3
65	172 47.75	1.25	"	31.1	1550	9.556 "	45.6	28.7		0.268	2λ min	52.5
110	172 26.83	1.417	"	49.0	2445	15.08 "	55.5	26.4		0.292	1λ	75.0
145	172 27.42	1.42	"	49.0	2445	15.08 "	56.4	26.7		0.305	1λ	72.8

Weight of motor with fan 15 lbs
without - 14 - 2 oz.

With 9Ω resistance in circuit of 116v. the fan speed is about 600 r.p.m. The machine was connected with a sewing machine by a small rope belt and the sewing machine was operated up to about 700 r.p.m. There was abundance of power, the motor running very rapidly. When the resistance was in circuit, the sewing machine ran at slow speed. If the motor was prevented from turning, with the resistance in circuit, the resistance wire became rather too warm. The diameter of this wire is 0.011" (No 31.S.) - The field is wound with silk covered wire, there being no S.C. wire of the size in stock.

Res: of armature	cool 14.22	hot	15.4
field	- 25.45	-	27.9
resistance	- 113.8		116.
	153.47		159.3

Inductance of field with armature in place + field current 3.13 H.



If r_1, r_2 are the radii of two indefinitely long horizontal and parallel wires
d be their centre distances apart
h " " common height from the ground

Their mutual capacity in cms per cm is

$$k = 2\log_e \frac{\sqrt{d^2+4h^2}}{d} \div 4 \left\{ \log_e \frac{2h}{r_1} \times \log_e \frac{2h}{r_2} - \left(\log_e \frac{\sqrt{d^2+4h^2}}{d}\right)^2 \right\}$$

Their mutual inductance in cms per cm is

$$\mu = \log_e \left(\frac{d^2 + 4h^2}{d^2} \right)$$

With $d = 0.5''$ $= 1.25$
" $r_1 = r_2 = 0.1'' = 0.25$
" $h = 1000$

$$k = 3 \times 2.3026 \times \log \frac{2000}{1.25} = 4.6052 \times \log 1600 = 4.6052 \times 3.204112 = 14.76$$

$$\div \left(2.3026 \log \frac{2000}{0.25}\right)^2 - \left(\log 1600 \times 2.3026\right)^2 \div 4$$

$$(2.3026 \log 8000)^2 - \left(\frac{14.76}{4}\right)^2 \div 4$$

$$(2.3026 \times 3.90309)^2 - \left(\frac{14.76}{4}\right)^2 = (8.988)^2 - (7.38)^2 = 80.78 - 54.46$$

$$= \frac{14.76}{26.32} = \frac{0.5607}{4} \text{ cms per cm} = \frac{0.5607}{4} \times 10^{12} = \frac{0.0623}{4} \times 10^{-5} \text{ fards per cm}$$

$$\frac{0.0623}{4} \times 10^{-7} \times 1.649 \times 10^{6} \text{ ohms}$$

$$\frac{10.2}{4} \times 10^{-2} = \frac{0.1021}{4}$$

$$\mu = 2.3026 \log \frac{4 \times 10^6}{1.5625} = 2.3026 \log 2.56 \times 10^6 = 2.3026 \times 6.40412 = 14.75 \text{ cms per cm.}$$

$$\frac{\mu}{k} = \frac{14.75 \times 10^{12} \times 4}{6.23 \times 10^{-12}} = 4 \times 2.368 \times 10^{12} \qquad \frac{2\mu}{K} = 1.874 \times 10^{13}$$

Calculation of ω_2 res. of two telephones $= 1.50 \times 10''$
inductance " " " $= 1.80 \times 10^{9}$

Let $n = 400$ $\therefore 2\pi n = 12.4246432 = 1.243 \times 10^{1} \times 2 = 2.1486 \times 10^{1} = p$

$$\omega_2 = \sqrt{(1.50)^2 \times 10^{22} + 4(1.243 \times 1.8)^2 \times 10^{22}}$$

$$\omega_2 = \sqrt{(2.25 + 20.04)10^{22}} = \sqrt{22.29} \times 10'' = 4.720 \times 10''$$

$$\frac{2\mu}{K\omega_2} = \frac{2 \times 0.0623 \times 10^{12}}{4.720 \times 10''} = \frac{1.9714 \times 10^{12}}{4.720 \times 10''} = 0.400 \times 10^{2} = 400 \omega$$

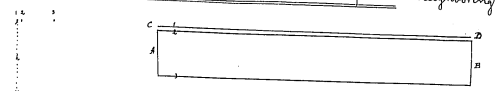
Calculation of ω_1 Bell telephone 80 ω × 1.14 H = 1.80 × 10¹⁶ and 1.6 × 10⁷
Transmitter 500 0.2 H

$2\pi n = 1.243 \times 10^{1}$

$$\omega_1 = \sqrt{(1.9)^2 \times 10^{32} + (2.486 \times 1.6)^2 \times 10^{14}}$$

$$= 2\sqrt{1.69 + 395.7} \times 10'' = 2\sqrt{397.4} \times 10'' = 4.0 \times 10^{12}$$

A problem in Telephonic induction between neighboring wires (109)



These wires are erected parallel and horizontal at an elevation h above the ground. The common radius of the wires is r. The distance between 1 and 2 is d. That between 1 & 3 D where D is so large relatively to d that its electrical influence upon 1 & 2 may be neglected. Then two cases are considered.

1st a simple harmonic e.m.f. e is impressed upon 1, with its other end free, the other side of the e.m.f. being grounded, and telephones are inserted in A & B. The e.m.f. has a frequency $p = 2\pi n$, and a maximum value E. The telephone at A & B have a resistance r apiece and an inductance λ. Electrostatic currents are established in these telephones.

2nd D is grounded and C is the transmitting end. The periodic e.m.f. will now send a current I through CD. Neglecting electrostatic action, what must be the impedance of the circuit CD in order that the sounds in the telephones may have the same loudness as in the previous case, the resistance of the loop AB being disregarded in comparison with 2r.

Case 1. Let k be the mutual electrostatic capacity of 1_1 and 1_2 per cm. abs. m.
$e = E \sin pt$

Then if q = the charge induced on 1_2 per cm (abs. measure)
$q = kxe$

Then current in each of the telephones $i = \frac{l}{2}\frac{dq}{dt} = \frac{kl}{2}\frac{de}{dt}$

Let ξ_1 = the electromotive force in the telephone (in arbitrary units)

Then $\xi_1 = \alpha \frac{di}{dt}$ where α is a constant

$$\therefore \xi_1 = \frac{\alpha k l}{2}\frac{d^2e}{dt^2} = \frac{\alpha k p^2 l E}{2} \sin pt.$$

Case 2. Let μ = the mutual inductance of 1_1 & 1_2
Then if ω_1 = " impedance of 1_1 abs. units
and ω_2 = " " " $1_2 + 1_3$ abs. units

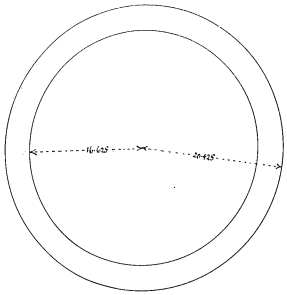
$$\gamma_2 = \frac{El\omega d \sin pt}{\omega_1\omega_2 dt} = \frac{El\omega \cos pt}{\omega_1\omega_2}$$

$$\xi_2 = \frac{\alpha l\mu E p^2 \sin pt}{\omega_1\omega_2}$$

For $\xi_1 = \xi_2$

$$\omega_1 = \frac{2\alpha\mu l E p^2 \sin pt}{\omega_2 \alpha k l p^2 E \sin pt} = \frac{2\mu}{k\omega_2}$$

Plan and Diametral Section of Standard Wooden Ring 1/4 Size
Made of 12 pieces of wood glued together.



		ft	ins
Mean internal radius	16.645	52.29	104.58
" external -	20.425	64.17	128.34
" - -	18.035	56.66	113.32
" diameter of core in plane of ring			3.78
" - - - - plane of axis			3.89

Weight of ring 560 gms.

The figure obtained by a cross section of the core is not by any means accurately circular. A fair approximation may be to call it an ellipse of diameter 3.78 and 3.89 respectively.
Its area on the assumption of being a circle of diam: 3.78 = 11.222
- - - - - - 3.89 = 11.885
an ellipse 11.55

The volume on this assumption is 6544 c.c.

Adding the diameter of the wire to the diameter of the core say 0.0432
the total diameter becomes 3.7855 + 0.0432 = 3.8287
The area of a strip on the outside of the wood = 0.0216 = 11.89 × 2.16 × 10⁻³ = 0.0257
This will increase the effective area to 11.8069

On the best dimensions of a standard wooden ring for use in measurements of magnetic permeability.

The ordinary rings of iron are 1" in diameter of core and μ may reach as high a value as 2000 with them. If the standard number of turns employed on an iron ring be 25 then if the area of the standard wooden core be double that of the iron core we need 25,000 turns of wire to obtain the same thing. With a ring 13" in int: diameter and #31 copper wire covered to 0.013" there is room for 3000 turns. The diameter of the wooden core may be 1.5"

The internal circumference as actually constructed had d 1.2" The wire selected is # 28 BWG 0.014" d.c.c. to 0.017". There will be room for 2000 turns very easily. The length of each turn will be 0.393' = 786' in all say 800 in round number. The resistance of all the turns in series will be 40 w. cool.

There are three dials on the apparatus

No. 1	registers	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, + 10
- 2	-	0, 10, 20, 30, 40, 50, 60, 70, 80, 90, + 100
3	-	0, 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 more
		Total 2010.

The resistances of the sections are

	10 turns	0.285 w
	100 -	2.295 w
	900 -	20.655 w
	1900 -	42.855 w
	2010 -	44.015 w.

The primary is wound in three layers as follows:-

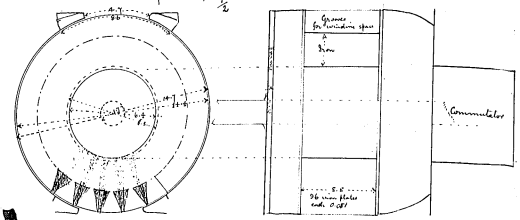
1st layer	360 turns.	diameter over wire	1 7/16"	res @ 19°C	0.262 w
2nd -	344 -	- - -	2"	- - -	0.285 w
3rd -	338 -	- - -	2 1/4"	- - -	0.297 w
Total	1042 -	- - -		- - -	0.844 w

		MMF	H	B for mean diam.	B for mean diam.
The MMF for the 1st layer per amp =	4π10.Ω. ÷ H =	3.998	46.18	47.20	
- - - 3rd - - - =	432.9	3.820	44.12	45.10	
- - - 1st + 2nd - - =	885.9	7.818	90.3	92.30	
- - - 3rd - - - =	425.3	3.753	43.35	44.31	
- - - 1st 2nd + 3rd - - =	1311.2	11.57	133.63	136.60	

The figures in the last column include the area of the wire.

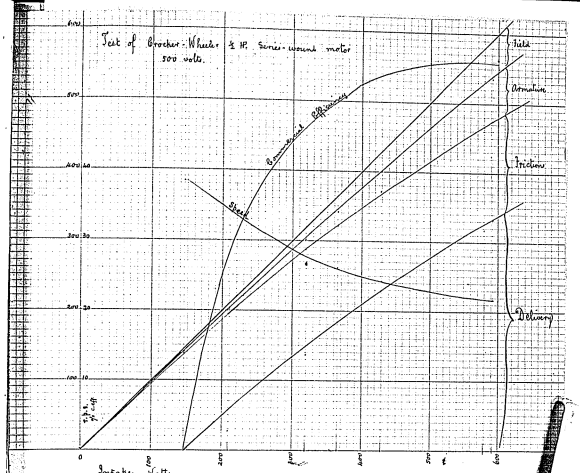
Cross Sections of Armature across and along axis

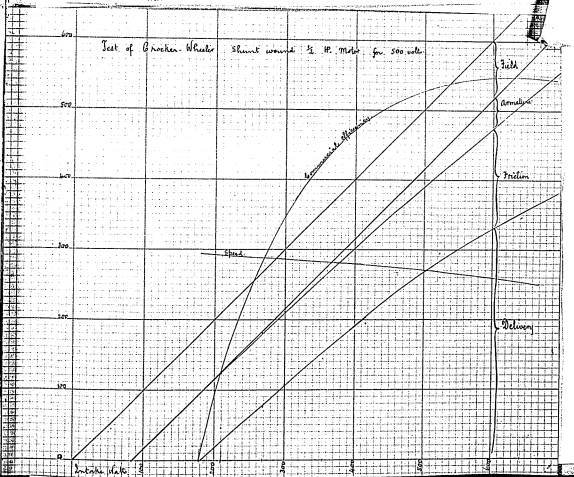
½



Test No.	P.D. at m.t.	Block	Amperes	Energy in motor	Res. of field	Drop in field	Energy in field	Energy in arm.	Res. of arm.	Drop in arm.	EMF of arm.	effect
1	482	0·058	0·303	146	34·46	10·44	3·16	143·8	40·0 ~~39·67~~	12·1	459·5	139
2	"	0·083	0·433	209	34·9	15·4	6·5	192·5		17·3	449·6	195
3	"	0·127	0·662	319	35·4	23·4	15·5	303·5		26·5	432·1	286
4	"	0·145	0·756	365	35·9	27·2	20·5	344·5		30·2	424·6	321
5	"	0·170	0·887	428	36·4	32·3	28·6	399·4		35·5	417·9	371
6	"	0·235	1·226	591	36·9	45·2	55·5	535·5		49·0	387·8	475·5
7	"	0·230	1·20	578	37·4	44·9	52·8	525·2	40·5	48·0	389·1	467

Test No.	P.D. at M.T.	Block	Current amp.	Energy in motor	Energy in arm.	Res. of arm.	Drop in arm.	Energy equal of arm.	E.M.F. of arm.	effect	Speed r.p.m.	r.p.m. r.p.s.	Current amp.
1	492	0·032	0·167	82·2		37·7							0
2	492	0·069	0·3587	177	94·8	"	7·3	1·4	484·7	93·4	1750	29·3	0·193
3	490	0·080	0·417	208·5	126·3	38·1	9·5	2·4	490·5	122·9	1740	29·0	0·25
4	490	0·105	0·547	268·1	195·9	38·5	14·6	5·6	475·4	190·3	1720	28·67	0·38
5	500	0·115	0·5995	300	217·8	39·9	16·8	7·3	482·2	210·5	1730	28·83	0·4325
6	502	0·135	0·7036	353·3	271·1	39·3	21·1	11·3	480·9	259·8	1720	28·67	0·5266
7	502	0·159	0·8283	416·3	334·1	39·9	24·3	17·4	475·7	316·7	1670	27·83	0·6619
8	502	0·200	1·043	523·7	441·15	39·9	35·0	30·7	465·7	410·8	1565	26·1	0·876
9	502	0·265	1·277	641·1	558·9	40·29	44·6	49·5	457·4	509·4	1515	25·25	1·110





Tests of Crocker-Wheeler 500-volt ½ H.P. Motors.

Two of these motors were received from the Edison General Electric Co. One was a series wound motor the other a shunt wound motor with a starting rheostat. The armatures in both machines seemed to be similar, as also the field frames, the only difference being in the field coils.

The armature has 24 sections like the commutator, each section being wound in a triangular groove, gramme ring fashion. The diameter of the wire is 0·0155" # 26 B&S. with 200 turns per section = 4800 wire all round. The cross section of the core is 5·5×2·40 = 13·2 sq. cms. reduced to 12·0 sq. cms by paper insulation between plates. The entrefer is about 0·15 the mean polar arc of embrace 16·5 cms reduced by grooves to about 11·5 cms. The polar area is thus about 63·25 sq. The pole is cut away circularly, between the limits shown. The core of the magnets is wrought iron and has a diameter of 5·4, or an area of 22·9 sq. cms. The wire on the series wound machine is # 20 B&S = 0·0319" D.C.C. & 0·0385". It res: on both spools (cond) is 34·4 ℧ = 17·23 ℧ per spool = 1700' and the mean diameter is 3·33" circ: = 10·48" = 0·87' = 1950 turns = 80 turns per layer + 24 layers.

The weight of the shunt wound machine with pulley complete 103 lbs
- - - - series - - - - - - - - 107-
- - - - armature 21 lbs. 9¾ oz.

The resistance of the field of the shunt wound machine is 3140 = cold and 3680 = hot, a ratio of increase of 1·172 equivalent to a rise of about 44·3° C.

Speed rpm	rps.	EMF per sec. per sec.	Balance		Moment	6165 Moment	Energy delivered	Friction	Mech. eff.	Elect. eff.	Load	Torque	
2300	38·3	12·0						139		0·954	light	11·25	
2080	34·7	12·96	250	5	1250	7·709×10⁶	26·8	168·2	0·128	0·933	4 pr. arc	·27	Series motor
1610	26·8	16·12	"	39·5	8374	5·165×10⁶	138·4	147·6	0·434	0·897	" S.E.F.	·30	
1570	26·2	16·2	"	45·5	11370	7·01 ×	183·7	137·3	0·503	0·881	load	·37	
1450	24·2	17·27	"	61·5	15370	9·47 ×	229·2	141·8	0·535	0·867	"	·39	
1300	21·7	17·87	250 500	59	24,750	15·26 ×	331·6	144·4	0·560	0·805	"	·45	
1245	20·8	18·7	"	"	"	- -	317·4	149·6	0·529	0·807	"	·55	

EMF per sec. per sec.	Balance		Moment	6165 × Moment	Energy delivered	Friction	Mech. eff.	Elect. eff. of motor	Load	Torque		
									field	14·50		
16·55						93·4	0·0	0·985	running	"		
16·92	250	40	2500	1·542 ×10⁷	4·52	77·7	0·217		driving	15·36	352,400	Series motor
16·58	250	17	4,250	2·620	75·1	105·2	0·280		S.E.F.	·40	℄ in arm 14,680	
16·73	"	24·5	6,125	3·776	108·7	101·8	0·362		1 λ	·42		Shunt
16·77	"	32·5	8,125	5·010	143·6	116·2	0·407		2 λ	·46		
17·10	"	45·5	11,375	7·012	195·1	121·6	0·469		3 λ			
17·9	"	73·5	18,375	11·33	295·7	115·1	0·565		5 λ	·50		
19·1	"	89·0	22,250	13·72	346·4	163·0	0·540	·910	7 λ	16·15		

Calibration of an Alternating Current Ammeter for Blinton Prison No. 4. 24th Mar. 91.

The Siemens dynamometer compared with the Obach gave the following

No. of Obs.	Obach	Sigma. Readings	Decimally	Sq. root	Mean	Obach	Amperes		Accepted results	Values in °
1	1.63	90°	90.	9.487	9.531	1.63	8.5	0.8918		1.258°
2	1.63	91°.30'	91.5	9.566						5.0°
3	1.63	91°.0	91.	9.539						11.3°
4	1.49	76°.20'	76.3	8.735	8.712	1.49	7.77	0.8918	0.892.	20.1°
5	1.49	75°.30'	75.5	8.689						31.4°
6	1.563	85°.50'	85.83	9.264	9.176	1.562	8.1444	0.8975	reciprocal 1.121	45.2°
7	1.56	82°.40'	82.6	9.088					1.255 recip. of reciprocal	61.5°
8	0.975	34°.0	34.	5.831	5.831	0.975	5.085	0.872		80.4°

The radius of the pointer to the scale center is 116.4 mm. The coil consisted of three layers of # copper wire. Two more layers were added making 5 in all. A mica vane supported on an aluminium arm was fixed to move in a brass box so as to act as a dampen.

The deflections given in the last column were marked off on the scale. The distances in chordal length travelled by the pointer referred to the mean radius of the scale are

1 amp. 0.82, 2 amp. 1.93, 3 amp. 3.17, 4 amp. 4.66, 5 amp. 5.86, 6 amp 6.78, 7 amp 7.4.

The res. of the ammeter is 0.058 ω. Its inductance at zero 0.148 h. at full load 0.7580 h.

The calibration was effected with a current from the Siemens alternator making 1780 rpm = 118 ~.

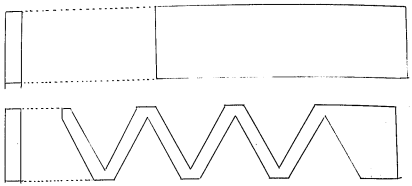
Telephone experiment 21st Mar. 91. 21 vol.

Took a small set of four magnet coils mounted on a revolving frame, and operated by a cord from the pulley of the CW arc ½ H. motor. At about 1500 rpm by estimation a clear note unaccompanied by any grating or other noise was heard in a distant telephone when a short length of its circuit say 4 cms long was held in front of one quadrant of the magnet frame so that the lines of force would cut it four times each revolution. The difficulty found was in attaining a sufficiently high steady speed.

On using a telephone in shunt on the a coil in circuit with one lamp, a loud note was heard in the telephone. This note was identified with Mi 5 of 1280 ~. There are 58 div. in a # 12 Brown commutator and the speed is 1300 rpm so that there would be 75,400 div. passed over per minute = 1257 ~ per second. On repeating the note in the telephone more carefully it was found to be at the #5 of Mi 5 with 1238 ~.

This sound could be heard inductively in a 50' length of green cord when some 4 amperes passed thro' the primary wire

Plan and section of one pair of carbons half size.



Arc Lighting Test. Commenced 23rd March 91.

A box of sample carbons was received from Mr Winslow Allderdice of Warren Ohio. These carbons were of special form and dimensions devised with the view of lasting 15 or 16 hours. The upper or + carbon is in the form of a strip; the lower carbon is zigzag. The dimensions of these carbons are shewn on the opposite page. They were set up on the 120 volt circuit with a lamp bank in series, and in a Wood lamp. The current required is about 10·0 amp. to produce a good arc.

The first pair marked #2 + 1 from the Faraday Carbon Co. of Pittsburg Pa. lasted 16 hours. The light was good but the arc was not always regular as the zigzag because the negative carbon did not wear level.

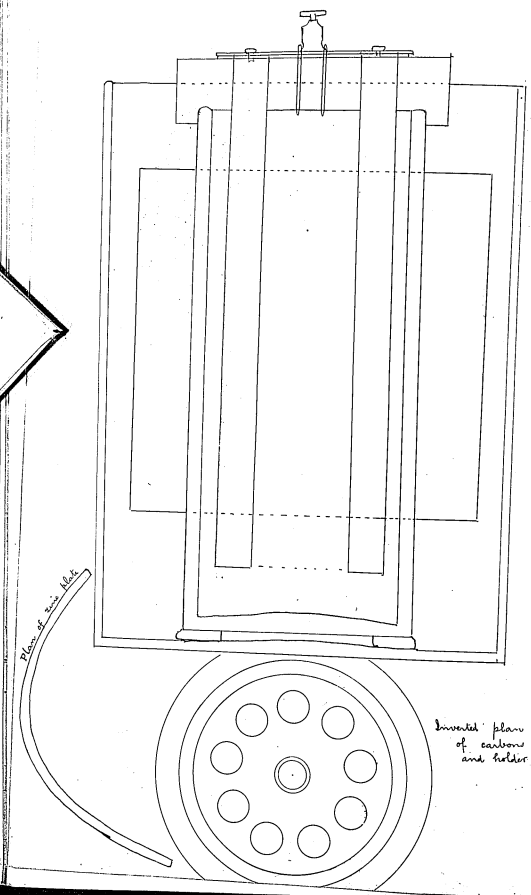
A second pair #3 from the Washington Carbon Co. of Washington. Weight of flat plate 117·5 grms, of zigzag 87·5g. Lasted 15 hours

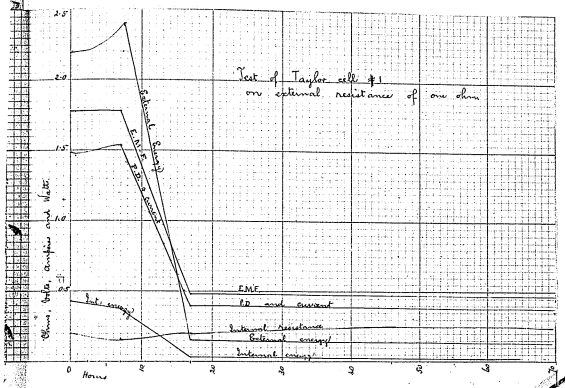
---

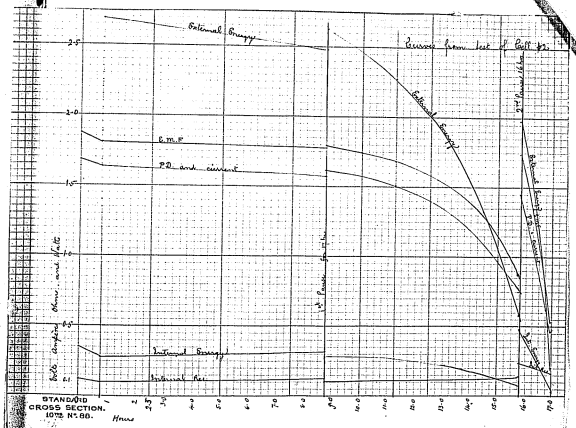
Measurement of the resistance and diameters of some copper wire stripped from a small induction coil – Medical – at the Phonograph Works. 22nd Mar. 91.

	Primary	Secondary
Diameter bare	0·0228"	0·00795"
" covered	s.c.c. 0·032"	0·012" d.c.c.
gauge number	23 B&S.	32 B&S.
Resistance @ 18°C	1·961 ω	122·6 ω
Feet per ohm	49.35	6·122
Length – feet	96·8'	750·4'
Lbs per ohm	0·0761	$1·171 \times 10^{-3}$
Weight	0·1492 lb.	0·1435 lb.

Full sized vertical section of Taylor cell with plan views of zinc and carbons.







STANDARD
CROSS SECTION.
10½ N.S.B.

Test of 2 cells of Taylor battery) 24th March 1891.

The dimensions of these cells appear on the opposite page. This cell is cheap to manufacture. Its negative element is carbon in the form of two ½" carbon rods. 6½" long as used in arc lamps. The positive element is zinc in the form of a plate bent circularly to conform with the jar, and heavily amalgamated. It rests on a pair of copper hooks which are not insulated in any way.

Time	Hours run since	EMF	P.D.	Current	Res. ext.	R. of cell	Ext. Energy	Int. Energy	EMF	P.D.	Current	res. ext. energy	R. of cell	int. energy
		Cell No. 1.							Cell No. 2.					
10.30	0	1.772	1.480	1.480	1Ω	0.2	2.19	0.446	1.772	1.492	1.492	2.22	0.19	0.446
11.15	0.75	1.768	1.460	1.460	"	0.2	2.13	0.43	1.732	1.460	1.460	2.13	0.19	0.43
12.05	2.5	1.768	1.492	1.492	"	0.185	2.22	0.461	1.748	1.484	1.484	2.2	0.18	0.40
12.30	7.0	1.790	1.540	1.540	"	0.156	2.37	0.37	1.792	1.480	1.480	2.19	0.21	0.46
1.30	14.0	0.480	0.400	0.400	"	0.20	0.16	0.032	0.510	0.432	0.432	0.187	0.18	0.014
3.30	46.0	0.472	0.371	0.378	"	0.25	0.14	0.035	0.476	0.392	0.392	0.154	0.21	0.032
7.20	70.0	0.440	0.356	0.356	"	0.24	0.13	0.031	0.444	0.372	0.372	0.139	0.19	0.027

The cells were set to work independently upon a resistance of one ohm of platinoid wire.

A second test was commenced on the 1st April with new solution but without reamalgamating the zinc.

Cell No.	Date	Time	Hrs fr start	EMF	PD	Current	res. ext	R. of cell	Ext. Energy	Int. Energy	Drop in the wire	EMF	PD	Current	drop	R. of cell	Ext. Energy	Int. Energy
1	Apr. 1st	12.0	0	1.890	1.608	1.608	1Ω	0.175	2.586	0.452	0.282	1.870	1.640	1.640	0.230	0.140	2.690	0.377
2	" 2nd	8.50	0	1.878	1.630	1.630	1	0.152	2.657	0.406	0.248	1.874	1.682	1.682	0.192	0.126	2.829	0.356
3		9.35	0.75	1.826	1.618	1.618	"	0.129	2.618	0.338	0.208	1.810	1.640	1.640	0.170	0.104	2.690	0.280
4		17.40	8.75	1.788	1.546	1.546	"	0.157	2.39	0.375	0.242	1.776	1.574	1.574	0.202	0.128	2.477	0.317
5	" 3rd	11.45	3.75	1.800	1.572	1.572	"	0.145	2.471	0.358	0.228	1.792	1.620	1.620	0.172	0.107	2.624	0.281
6		13.15	11.25	1.684	1.460	1.460	"	0.153	2.132	0.326	0.224	1.682	1.506	1.506	0.176	0.117	2.268	0.265
		17.50	15.8	0.864	0.722	0.722	"	0.197	0.521	0.103	0.142	0.854	0.752	0.752	0.102	0.136	0.566	0.077
4	4th	9.30	15.5	1.758	1.388	1.388	"	0.267	1.926	0.514	0.370	1.740	1.504	1.504	0.236	0.239	1.971	0.471
		16.45	17.	0.590	0.460	0.460	"	0.266	0.217	0.077	0.124	0.530	0.458	0.458	0.074	0.162	0.209	0.034

Record of some tests made on the fall of pressure in the feeders of the 26th Street Edison Station.
made 25th March 1890.

In order to determine how closely the fall of pressure of in the feeder coincided with their resistance ~~add~~ given in our tables, set up a potentiometer in the gallery of the 26th St. Station and determined the difference of pressure between the negative bus bar and the feeding points through the pressure wire.

No. of feeder	No. of Feeder.	Length	Cir. mils	Resistance by tables.	Total Ohms.	Amperes	Balance	Drop by calculation	Drop by Potentiometer	Obs – Calc: Discrepancy
								volts	volts	
1	I	1370	350 + 400	2.86×10^{-5}	3.92×10^{-2}	115	$\frac{2.70}{2.80} = \frac{2.9}{2.1}$	4.51	3.2	−1.21
2	II	1800	300 + 350	3.4×10^{-5}	6.12×10^{-2}	70	$\frac{2.65}{2.70} = \frac{2.65}{2.70}$	4.28	3.80	−0.48
3	III	1080	500	2.174×10^{-5}	2.348×10^{-2}	125	$\frac{2.60}{2.70} = 2.65$	2.94	3.80	+0.86
4	IV	1100	400	2.613×10^{-5}	2.875×10^{-2}	115	$\frac{2.70}{2.80} = \frac{2.75}{2.5}$	3.31	3.55	+0.24
5	V	550	250	4.3×10^{-5}	2.365×10^{-2}	160	$\frac{2.50}{2.80} = \frac{2.083}{2.0}$	3.78	4.42	+0.64
6	VI	1050	550	1.976×10^{-5}	2.075×10^{-2}	120	$\frac{2.60}{2.80} = \frac{2.733}{2.65}$	2.49	3.92	+1.43
7	VII	2580	450	2.415×10^{-5}	6.23×10^{-2}	85	$\frac{2.60}{2.80} = \frac{2.05}{2.5}$	1.84	4.23	+2.39
8	IX	2320	350	3.1×10^{-5}	7.19×10^{-2}	90	$\frac{2.60}{2.80} = \frac{2.15}{2.1}$	6.47	3.09	−3.38
9	X	820	250	4.3×10^{-5}	3.526×10^{-2}	85	$\frac{2.70}{2.80} = \frac{2.37}{2.4}$	3.00	3.40	+0.40
10	XI	1400	500	2.174×10^{-5}	3.044×10^{-2}	90	$\frac{2.70}{2.80} = \frac{2.57}{2.65}$	2.74	3.69	+0.95
11	.	11				90	$\frac{2.60}{2.80} = \frac{2.60}{2.65}$		4.0	
12	XIII	2480	350	3.1×10^{-5}	7.69×10^{-2}	65	$\frac{2.60}{2.80} = \frac{2.5}{2.65}$	2.15	4.0	+1.85
13						65	$\frac{2.60}{2.80} = \frac{2.5}{2.6}$		3.59	
14						70	$\frac{2.60}{2.80} = \frac{2.73}{2.55}$		3.92	
15	XII	1500	400	2.613×10^{-5}	3.920×10^{-2}	60	$\frac{2.60}{2.80} = \frac{2.6}{2.6}$	2.35	3.44	+1.09
16	XIV	1750	500	2.174×10^{-5}	3.805×10^{-2}	105	$\frac{2.60}{2.80} = \frac{2.7}{2.7}$	4.00	3.88	−0.12
17	XVIII	650	250	4.3×10^{-5}	2.794×10^{-2}	65	$\frac{2.60}{2.80} = 2.71$	1.82	3.92	+2.10
18	XIX	3350	(2070 + 1280)	2.86×10^{-5}	5.92×10^{-2}	100	$\frac{2.60}{2.80} = \frac{2.95}{2.95}$	0.59	1.87	+1.27
			(300 + 600)	1.522×10^{-5}	2.29×10^{-2}			2.29	4.28	
19	XXI	2300	400	2.613×10^{-5}	6.01×10^{-2}	70	$\frac{2.60}{2.80} = \frac{2.77}{2.75}$	5.28	4.27	−0.35
20	XXIX	1350	450	2.415×10^{-5}	3.26×10^{-2}	70	$\frac{2.60}{2.80} = \frac{2.42}{2.5}$	2.28	2.27	+0.99
21	XXX	1300	450	2.415×10^{-5}	3.14×10^{-2}	75	$\frac{2.60}{2.80} = 2.2$	2.36	3.39	+1.03
22										
23										
24										

249.0 volts across bus-bars
1140 feet of cable same size as feeder in circuit with each feeder within the limits of the building).

Sum of + discrepancies 15.34
− 5.54
Excess in 18 9.80
average 0.54 volts more drop observed than ought to exist.

110 divs × 6·25 = 687·5 divs. thro. 301,000 ω 1 cell.
50 Aghll. charging 1 ℓ give 20 × 217·7 = 4354 divs: } ratio 53·75
1 " " " " " " " 81

∴ 50 Aghll. thro 301,000 ω give 687·5 × 53·75 = 36,960 divs:
or 1 div: represents 36960×10^{-4} $3{\cdot}01 \times 10^{-1}$ megohms = $11{\cdot}13 \times 10^{3}$ = 11,130 Ω

$\frac{D}{d} = \frac{175}{102} = 1{\cdot}716$ $\log_e \frac{D}{d} = 0{\cdot}54$ $0{\cdot}075 \times 0{\cdot}54$

$\frac{V}{v} = \frac{320}{306} = 1{\cdot}046$ log 1·046 = 0·01953 × 2·303 = 0·04498
70 ÷ (0·04498 × 0·075) = $70/4{\cdot}498 \times 7{\cdot}75 \times 10^{-3}$ = $70/3{\cdot}374 \times 10^{-3}$
= $20{\cdot}75 \times 10^{3}$ = 20,750 Ω

$\frac{V}{v} = \frac{266{\cdot}5}{231{\cdot}5} = 1{\cdot}151$ log 1·151 = 0·06070 × 2·303 = 0·1232
60 ÷ (0·1232 × 0·064) = $60/1{\cdot}232 \times 2{\cdot}9 \times 10^{-2}$ = $60/3{\cdot}573 \times 10^{-2}$ = $1{\cdot}679 \times 10^{3}$

$\frac{V}{v} = \frac{461{\cdot}5}{387{\cdot}5} = 1{\cdot}191$ log 1·191 = 0·07591 × 2·303 = 0·1748
60 ÷ (0·1748 × 0·106) = 60/0·01853 = 3240

Telephonic experiments. 24th March.

Took the 1000 feet of Amins cable a test of which is given in the record for 27th February 1888.
The following tests were made of this cable, after it had been taken out of its tank, uncoiled and layed in an irregular loop round the premises on the ground.

Insulation by Direct Deflection. Constant ½ Aghll.
through 300,000 ω G. 5250 (Wallitis) shunted by 1000 ω = 110 divs.
1 Aghll. charging 1 ℓ 81 divs: 50 Aghll: charging 0·05 ℓ 217·7 divs:

Insulation of interior wire to exterior wire by direct deflection 50 Aghll 2 ∞
1·5 divs. = 7416 Ω abs.
Insulation of exterior strand by direct deflection 50 Aghll. 2 ∞ 5 divs
= 2226 Ω abs.

Insulation by full of charge, using 50 Aghll. cells and Wallitis G.
Interior strand, with exterior grounded. Charge 320 divs:
After one minute insulation charge (70 ∞) 14 "
= 20,750 Ω
Interior strand free, exterior strand charged. Charge 266 divs:
after one minute of insulation charge 35 "
= 16,790 Ω
Interior strand grounded, exterior strand charged, Charge 461·5 divs
After one minute of insulation charge 74
= 3,240 Ω

Capacity of inner strand to ground outer strand free 0·020 ℓ
" " " " " " " grounded 0·075 ℓ
" " outer " " " inner " free 0·029 ℓ
" " " " " " " grounded 0·106 ℓ.
These measurements are with Jolchmmeter.
The cable was dry on comparatively dry ground

Resistance of interior conductor 2·4 15 ω ⊃ abt 12° C.
" " exterior " 0·497 ω " " "

Inductance balance with Jolchmmeter 1000/10 2·534 ω 0·216 ℓ interior
" " " " 1000/10 0·616 ω 0·85 ℓ exterior

No change in either balance discernible when the other strand was inserted in the battery cct. shewing that the mutual inductance is negligible.

The following are the dimensions of the core :-

Inner conductor of 7 wire each 0·025"
strand diam 0·102
Diam. G.P. covering 0·175"
Outer conductor of 18 wire each 0·036"
Diam. over strand 0·247"
" of g.p. covering 0·370"
" of ext. binding 0·425"

Telephonic Experiments continued.

A telephone of the ordinary Bell type marked # 144,040 A has a resistance @ 24° C of 73 ω and an inductance of 113.4 H. It was joined across the mains with resistance inserted until the note $\frac{1300 \times 55}{60}$ or 1287 ~ per sec mentioned on page 112 just ceased to be heard. The resistance required was a coreless induction coil secondary having a resistance of 45,200 ω and an inductance of 22.6 H.

No. 1. The neutral wire of the 3-wire system was now grounded, and the terminal joined to the external core through another telephone B the internal core being free. The note was heard in this telephone. ~~too~~

No. 2. The external strand was now grounded through telephone A. B's note was now louder. A's note was about equally loud.

No. 3. The β end of the external strand was now grounded. The note in A entirely ceased. B's note remains unaltered in strength but a higher shrill note was superposed upon it.

No. 4. The external strand was now connected through B to the dynamo, the interior strand free. B sounded a distinct note.

No. 5. The α end of the interior strand was grounded through A. Loud sounds in B and A.

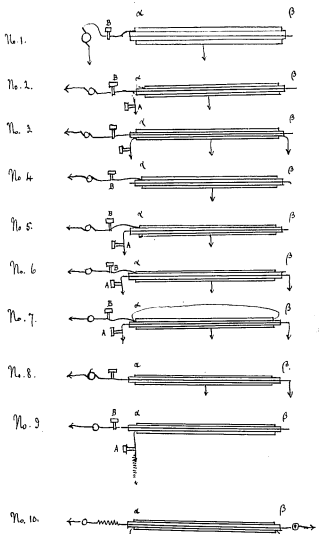
No. 6. The β end of the interior strand was now grounded direct. Loud sounds in B, with a fainter shrill note superposed. Silence in A.

No. 7. The β and α ends of the exterior strand are directly connected without any change in the high superposed note of B.

No. 8. The dynamo was connected with the interior strand of the wire through B, the exterior strand free. Faint note in B.

No. 9. The dynamo was connected with the interior strand of the wire and the exterior grounded through A and a resistance. This resistance was increased until the sounds in A just reached the limit of clear audibility. This resistance was 348,000 ω with an inductance of 44.3 H = 493,000 ω impedance to pure sine wave.

No. 10. B. was now removed, and a current sent through the interior strand, graduated by a lamp bank and read with a galvanometer. The limiting conditions for electromagnetic induction



No. of Obs.	Current in Black	Primary amperes	Sound in 1st exp.	Pitch in 1st exp.	Pitch in 2nd exp.	Sound in 2nd exp.	Sound in A	Comparison for exp.	Primary Amp.	Secondary Amp.
1	0.073	0.5215	–	229.7	60,000	0.113	just audible	1	240	$\frac{1.9 \times 10^6}{110,000}$
2	0.142	0.740	–	168.9	110,000	0.113	–	2	169	$\frac{1.87 \times 10^6}{110,000}$
3	0.272	1.419	–	88.1	200,000	–	–	4	88.1	$\frac{1.76 \times 10^6}{200,000}$
4	0.500	2.608	–	47.9	400,000	–	–	8	47.9	$\frac{1.91 \times 10^6}{400,000}$
5	0.532	2.774	4.964	45.07	110,000	–	–	9	59.7	$\frac{1.62 \times 10^6}{110,000}$
6	0.55	2.868	37.94	43.59	20,000	–	–	12	302.5	$\frac{6.05 \times 10^6}{20,000}$
7	0.500	2.608	–	47.9	400,000	–	–	8	47.9	$\frac{1.91 \times 10^6}{400,000}$

$$\frac{1.257^2 \times 10^6 \times 4.96^2 \times 10^2}{4.507^2 \times 10^{10}} = \frac{1.580 \times 24.6}{20.313} \times 10^{-2} = 1.914 \times 10^{-2} \times 4\pi^2 = 0.01914 \times 4\pi^2 = 0.7554$$

$$\sqrt{1.7554} = 1.325 \times 45.07 = 59.73$$

$$p^2 = 6.24 \times 10^7 \qquad 6.24 \times 10^7 \times 37.9^2 \times 10^{-2} = 6.24 \times 14.364 \times 10^3 = 89.62 \times 10^3 = 8.962 \times 10^4$$

$$R^2 = 19.00 \quad , \quad 89.620 + 19.00 = 91.520 = (302.5)^2$$

$$(3.148 \times 10^5)^2 = 12.11 \times 10^{10} \qquad p^2 = 6.24 \times 10^7 \qquad 6.24 \times 10^7 \times 4.148^2 \times 10^2 = 19.62 \times 10^9 \times 6.24$$

$$= 122.5 \times 10^9 = 1.225 \times 10^{11} + 1.211 \times 10^{11} = 2.436 \times 10^{11} = 24.36 \times 10^{10} = (4.93 \times \pi^2)$$

$$p^2 h^2 r^2 = 6.24 \times 10^7 \times (19.1)^2 \times 10^{-14} \times 10^{-24} \times (3.48)^2 \times 10^{29} = 6.24 \times 56.25 \times 12.11 \times 11^2 = 4.252 \times 10^4$$

$$\ell k p^2 = 4.45^2 \times 10^{10} \times 7.8 \times 10^{-17} \times 6.24 \times 10^7 = 2.47 \times 10^{-6} = (-206.47)^2 + 42600 + 42520 = 85120 = 292^2$$

Comparison of Ammeters 27th March 1891.

As a check upon the accuracy of the results obtained both the feeders in 26th St. Station as recorded on p. 115, an ammeter from one of these feeders was by the courtesy of the Superintendent furnished to the Laboratory for testing. Three other large ammeters from the Laboratory were tested at the same time. The feeder ammeter is marked #19 but not + or –

No. of Obs.	P.D. on Large Shunt Leg. volts	Res. of Shunt	Current Amp.	Shunt Deft.	Current Amperes	Feeder ammeter	Dum 400 ammeter	1000 ammeter #1	1000 ammeter #2	% diff. Feeder Ammeter	
1	0.0[illegible]2	0.00162	38.3	7.14	37.23	33	35			-53	13.8
2	0.088	Lect – 22°C.	54.33			52.5	61	50	50	-1.8	3.3
3	0.192		118.5			115	115	110	110	-3.5	3.0
4	0.268		165.5			160	160	150	150	-5.5	3.3
5	0.278		171.6			165	165	150	150	-6.6	3.9
6	0.362		223.5			217	220	205	205	-6.5	2.9
7	0.442		272.9			262	262	250	260	-10.9	4.0

Determination of Field Winding for the 120-volt 1 H.P. Shunt Edison small motor 1st April 91.

From the results given on page 121 it is evident that we require 2000 ampere turns. With 0.30 amp this means 6700 turns of wire. The resistance hot must be $\frac{120}{0.3}$ = 400 ω. The length of the interplange is 4.425" and the core diameter 2.625". Depth of winding say 0.9" = 4.425" ext. diam. The mean diameter will thus be 3.525" = 11.08 = 0.092'. 6700 × 0.092 = 6183 say 6200' for 400 ω = 15.5' per ω @ 60°C. This is represented most nearly by #28 + #29 BWG, 0.0124" and 0.013".

0.0124" #28 BWG = 0.0126" cond. 400 ω @ 0.09866 lbs and 16.59' = 3.94 lbs = 6640'
0.013" #29 BWG = 0.023" – 400 ω 0.1733 – 4.31 = 2.92 = 4920'

No. 28 will be preferable. There would then be 160 turns per layer and 6800 turns = 42.6 layers = 1" depth.

Result 4 lbs. of #28 BWG copper wire. Probably 5 lbs. of covered wire.

Meeting of the Committee on Lightning Protection appointed by the Association of Edison Companies

A meeting of this Committee took place on the 28th March 91.

Mess. W. Jackson + W. S. Howell members.

It was decided to try lightning arresters of which samples were prepared. Two sheets of lead foil 6" × 2' are laid up parallel to their width upon a sheet of paraffined paper about 0.015" thick. In this way a condenser is obtained in the form of a roll and has a capacity varying from 0.02 μf to 0.027 μf. One electrode is brought out in the form of a stout lead wire serving as a safety catch to break a dynamo spark. The other is grounded through a copper wire. The roll is inserted in a sealed zinc tube with a band for support soldered on.

On the equations of motion in a simple inductance circuit under the action of periodic impressed electromotive forces.

Assuming a periodic emf. of instantaneous value e, & a constant inductance L

We have $e = cr + L\dot{c}$

$$\dot{c} + \frac{cr}{L} = \frac{e}{L} \quad \text{and if } \frac{r}{L} = P \;,\; \frac{e}{L} = Q \;,\; y = c, \text{ this becomes}$$

$$\frac{dy}{dx} + Py = Q \;,\; \text{a standard form of which the solution is}$$

$$y = K\varepsilon^{-\int P dx} + \varepsilon^{-\int P dx}\int Q\,\varepsilon^{\int P dx}dx$$

(1) . . . . . or $c = K\varepsilon^{-\int \frac{r}{L}dt} + \varepsilon^{-\int \frac{r}{L}dt}\int\left(\frac{e}{L}\varepsilon^{\int \frac{r}{L}dt}\right)dt$ Now let $e = \varphi(t)$

(2) . . . . . $c = K\varepsilon^{-\frac{t}{T}} + \varepsilon^{-\frac{t}{T}}\frac{1}{L}\int \varphi(t)\,\varepsilon^{\frac{t}{T}}dt$ where $T = \frac{L}{r}$ . . . . . (a)

Let $e = \varphi(t) = E\sin(\alpha t + \beta)$

by (2) $c = K\varepsilon^{-\frac{t}{T}} + \varepsilon^{-\frac{t}{T}}\frac{E}{L}\int \varepsilon^{\frac{t}{T}}\sin(\alpha t+\beta)\,dt.$

$$= K\varepsilon^{-\frac{t}{T}} + \varepsilon^{-\frac{t}{T}}\frac{E}{L}\left[\frac{\varepsilon^{\frac{t}{T}}\left\{\frac{1}{T}\sin(\alpha t+\beta) - \alpha\cos(\alpha t+\beta)\right\}}{\frac{1}{T^2} + \alpha^2}\right]$$

$$= K\varepsilon^{-\frac{t}{T}} + \frac{E\left\{\sin(\alpha t+\beta) - \alpha T\cos(\alpha t+\beta)\right\}}{r(1+\alpha^2T^2)}$$

$$= K\varepsilon^{-\frac{t}{T}} + \frac{E\sin(\alpha t+\beta-\tan^{-1}\alpha T)}{r\sqrt{1+\alpha^2T^2}}$$

Also with $c = 0$ at $t = 0$

$$c = \frac{E\sin(\alpha t+\beta-\tan^{-1}\alpha T)}{r\sqrt{1+\alpha^2T^2}}\left(1-\varepsilon^{-\frac{t}{T}}\right) \quad \text{- - - - - - - - - - - - - (3)}$$

This is the current in a circuit subject to a simple harmonic emf.

Now let $e = \varphi(t) = E_1\sin(\alpha_1 t+\beta_1) + E_2\sin(\alpha_2 t+\beta_2) + E_3\sin(\alpha_3 t+\beta_3) + \text{etc.}$

by (2) $c = K\varepsilon^{-\frac{t}{T}} + \varepsilon^{-\frac{t}{T}}\frac{1}{L}\int\left\{E_1\sin(\alpha_1 t+\beta_1)\varepsilon^{\frac{t}{T}} + E_2\sin(\alpha_2 t+\beta_2)\varepsilon^{\frac{t}{T}} + \quad\right\}dt$

$$= K\varepsilon^{-\frac{t}{T}} + \varepsilon^{-\frac{t}{T}}\frac{E_1}{L}\int\sin(\alpha_1 t+\beta_1)\varepsilon^{\frac{t}{T}}dt + \varepsilon^{-\frac{t}{T}}\frac{E_2}{L}\int\sin(\alpha_2 t+\beta_2)\varepsilon^{\frac{t}{T}}dt + \text{etc.}$$

$$= K\varepsilon^{-\frac{t}{T}} + \frac{E_1\sin(\alpha_1 t+\beta_1-\tan^{-1}\alpha_1 T)}{r\sqrt{1+\alpha_1^2T^2}} + E_2\frac{\sin(\alpha_2 t+\beta_2-\tan^{-1}\alpha_2 T)}{r\sqrt{1+\alpha_2^2T^2}} + \text{etc.}$$

and with $c = 0$ at $t = 0$

$$c = \Sigma\left\{\frac{E\sin(\alpha t+\beta-\tan^{-1}\alpha t)}{r\sqrt{1+\alpha^2T^2}}\right\}\left(1-\varepsilon^{-\frac{t}{T}}\right)$$

Test No.	Time	P.D. in volts	Ohms	Amperes	Energy in watts	Rise of temperature	Drop in temperature	Energy in watts	Energy in watts	Amps of field	Drop in field	Energy in watts	Effect
1	14.30	220	0.092	0.48	105.6	20.8	10.0	4.8	104.8	3.47	1.7	0.8	100
2	14.35	244	0.123	0.64	156.2	21.	13.4	8.6	154.8	3.5	2.2	1.4	148.2
3	15.04	243.5	0.155	0.808	196.7	21.2	17.1	13.8	194.4	3.53	2.9	2.3	189.4
4	.07	244	0.204	1.064	260	21.4	22.8	21.3	256	3.56	3.8	4.0	251.7
5	.10	244	0.240	1.250	305.0	21.6	27.0	33.8	299.4	3.59	4.5	5.6	295.6
6	.15	243	0.361	1.880	457.0	21.8	41.0	77.1	444.2	3.62	6.8	12.8	437.1
7	.20	243	0.476	2.586	628.0	22.0	56.9	147.2	593.7	3.65	9.4	24.3	446.5
8	16.10	241	0.472	2.46	593.0	22.2	54.6	134.3	570.6	3.69	9.1	22.4	436.3
9	.13	242	0.540	2.816	681.6	22.2	62.5	176.0	652.3	3.70	10.4	29.3	476.3

PARTICULARS OF EDISON MODEL [illegible] HP. [illegible] SERIES MOTOR.

[illegible] on wooden base with [illegible] of [illegible] DIA.

Starting [illegible] ring and series field.

Voltage at machine terminals 250.

Amperes at delivery of 400 watts. [illegible] running light 0.9 amp.

Commercial efficiency at full load [illegible] % at half load 60 %

Speed running light 5000 r.p.m. at full load 1400 r.p.m.

Dimensions :- Armature body

External diameter 6 ", internal 4".

grooves 42 on each side.

Breadth of armature body over teeth 1.45"

" " at base of grooves 1.0"

Depth of grooves 0.28", breadth 0.25"

Band iron in core prepared at Schenectady Works.

Cross -Section of armature core, 1.8 sq. in.

Breadth of teeth 0.15" at external, 0.01" at internal circle.

Polar surface of teeth [illegible] sq. ins. under each pole.

Winding 420 turns viz:- 6 layers of 70 turns each of [illegible] SWG.

size 0.016" covered to 0.0225"

Commutator diam. 5.2" Gramm either connections 0.06"

Armature groove insulation 0.01" wire at sides, 0.01" wind stick in base.

Total weight of wire on armature [illegible] lb. length about [illegible]

Resistance of armature between brushes including commutator connections 0.20 ohms cool [illegible] ohms hot.

Current in armature at full load 2. [illegible]

Drop in armature at full load 40 volts.

Ampere-turns required in [illegible] armature at full load and [illegible] stamping flux through armature section of [illegible] 100,000 CGS.

Total [illegible] density [illegible] 15,000

[illegible]

[illegible] and [illegible]

[illegible]

[illegible] 300,000

[illegible] 7,400

[illegible] 0.051" reduced to 0.051"

[illegible] ohms hot.

[illegible] 10 [illegible]

[illegible] ohms cold, [illegible] hot.

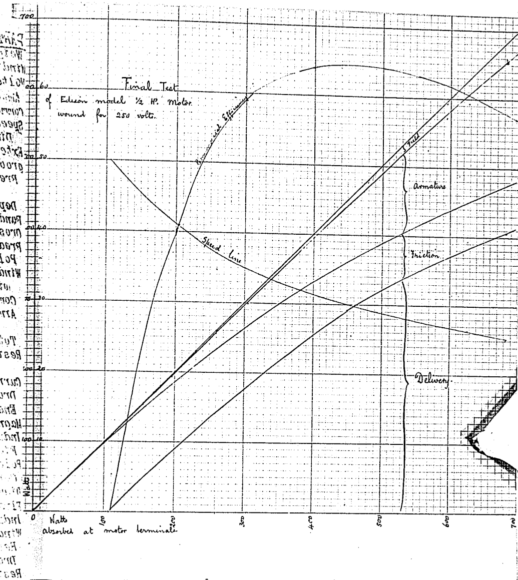
[illegible]

[illegible]

[illegible]

[illegible]

The [illegible] weight.


Final Test
of Edison model ½ H.P. Motor
wound for 250 volts.
Commercial Efficiency
Field
Armature
Friction
Delivery
Speed line
Watts
Watts absorbed at motor terminals

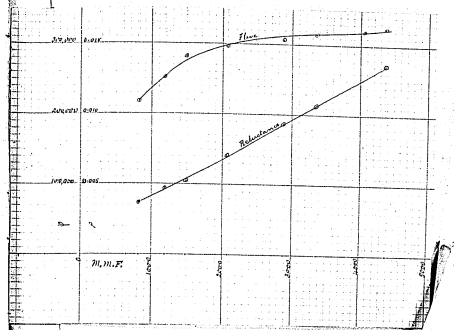
Test of the model ½ H.P. 250 volt motor Series wound 27.III.90. (20)

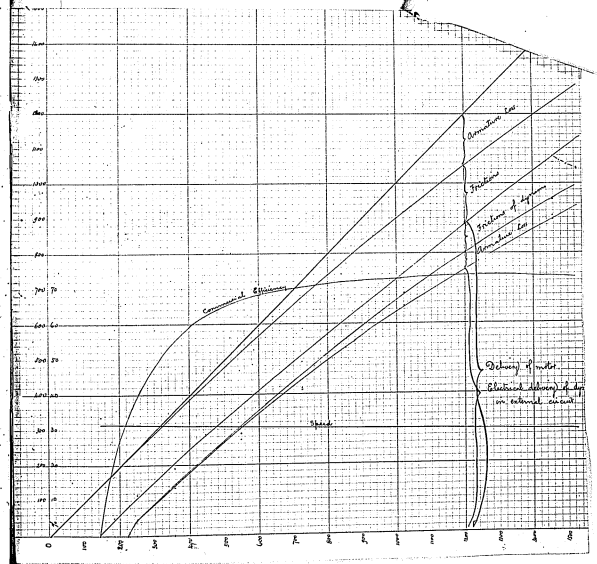
The resistance of the armature coil is 20.83 ω field 3.470 ω
" " " " hot " 22.16 " " 3.70 "

The motor was set in the large tank and balanced to drive the 1000 ft.

Speed r.p.m.	r.p.s.	E.M.F. generated	Opts. per Amp.	Balance		Moment	6165 ÷ Moment	Driving	Friction	Efficiency η	Commercial η	Sound	
3000	50	208.3	4.16	"		–	∞	–	–	0.947		Free	
2705	45.1	228.4	5.07	250	0.23	5750	3.946	160	–	0.936	1	Dynamo	
2400	40	226.8	5.67	250	0.26	6400	3.946	158	22.6	0.932	0.893	S.E.F	
2210	36.8	225.9	6.14	250	0.37	9250	5.703	210	21.7	0.926	0.888	1 λ	
2080	34.7	212.5	6.12	250	0.45	11,250	6.936	244	24.6	0.871	0.790	2 "	
1830	30.5	195.2	6.40	250 500	0.23 0.20	15,750	9.710	296	71.0	0.803	0.648	4 "	
1580	26.3	176.7	6.72	250 500	0.55 0.20	23,750	1.464	385	61.0	0.727	0.613	6 "	
1600	26.7	177.3	6.64	"		"	"	391	45.3	0.730	0.659	" "	
1500	25.0	169.1	6.76	250 500	0.65 0.22	26,250	1.618	405	71.3	0.736	0.594	8 "	
										~~0.699~~			

No. of Obs. Time	P.D. on M.T.	Ohmic	Current supplied M	Resistance in circuit	Energy in circuit	drop volts	Energy lost in armature	Effort	Speed of armature r.p.s.	EMF	EMF per h.p.
14.50 1		-							0	-	
.51 2	123.5	0.290	1.512	1.22 Ω	186.7	1.8	2.7	154	1890	31.5	121.7	3.86
5.00 3	122.0	0.355	1.851	1.25	225.7	2.3	4.3	227.4	1860	31.0	119.7	3.86
.13 4	122.5	0.390	2.034	1.25	249.2	2.6	5.3	249.9	1880	31.3	119.9	3.83
.17 5	122.0	0.562	2.931	1.31	357.6	3.8	11.1	346.5	1855	30.92	118.2	3.82
.21 6	121.5	0.705	3.677	1.34	446.7	4.9	18.0	428.7	1840	30.67	116.6	3.80
.25 7	121.0	0.705	3.677	1.37	444.9	5.0	18.4	426.5	1835	30.6	116.0	3.79
.29 8	121.5	0.670	4.537	1.40	551.3	6.4	28.8	522.5	1835	30.6	115.1	3.76
5.33 9	121.5	1.15	5.996	1.43	728.4	8.6	51.4	677.0	1815	30.25	112.9	3.73
.37 10	121.5	1.35	7.04	1.46	855.2	10.3	72.4	772.8	1770	29.5	111.2	3.77
.41 11	120	1.64	8.551	1.49	1026	12.7	109.0	917.	1765	29.42	107.3	3.65
.45 12	119	2.35	12.25	1.50	1458	18.4	225.0	1233	1750	29.12	100.6	3.46
5.50 13	119.5	2.45	12.74	1.50 μ	1527	19.2	245.0	1282	1740	29.0	100.3	3.46





Test of 1 H.P. 120-volt motor 31st March 1891

The motor has mitis iron fields with laminated pole pieces made up of strips each ·1 thick. The pole pieces are strapped to the polar extensions. There are 9 layers of 77 turns on the field magnet

No. of Exp.	Lamps in field	Ring Amps.	Amperes 2.0235	Amp Turns	MMF	Ohmic	Amperes in armature	Profiles	E.M.F. G.M.T.	E.M.F. generated	φ	Z	ρ	Speed
1	14	0.06617	5.030	3486	4.381	0.228	1.189	1.144	120.5	119.1	3232.X10⁸	16,160	1.35x10⁸	1755
2	10	0.51503	3.879	2688	3380	0.232	1.21	1.147	-	119.0	3.148 ..	15,740	1.07x10⁸	1800
3	8	0.44001	3.314	2297	2.887	0.232	"	"	-	-	3076 ..	15,380	9.32x10⁷	1850
4	6	0.31640	2.387	1654	2079	-	-	-	121	119.5	2.964 ..	14,820	7.06 "	1920
5	4	0.22629	1.704	1181	1485	-	-	-	121	119.5	2.811 ..	14,060	5.28 "	2025
6	3	0.18053	1.3623	944.8	1186	0.244	1.272	1.55	-	119.5	2.528 ..	12,640	3.169 "	2250
7	2	0.12279	0.9226	639.7	805.4	0.268	1.397	1.70	-	119.3	2.486	10,930	3.666 "	2400

The resistance of the armature between brushes cold = 1.216 ω
" " across diameter cold 1.465 ω
field cold 3.12 ω

Efficiency test of 1 H.P. 120-volt motor with its field separately excited.

Balance	Moment	Giles Moment	Declining	Friction	P.D. at Dy Terms	Ring Amps	Amperes	Brit: no. of dynamo	Amp.	EMF	Energy Watts in	Energy Watts out
250 @ 19												
@ 27	2500	1.574 x 10⁸	149.6 0.240	1825.4								
@ 36.7	4425	2.721	184.6 0.375	136.8								
@ 42.5	5875	3.622	113.4 0.455	130.5	109.5	0.05333	1.147	1.00 ω	1.15	109.9	2.57	1.85
@ 54	10,000	6.165	190.6 0.533	155.9	108.5	0.16236	1.227		1.2	109.7	133.1	134.6
250 @ 19 / 500 @ 30 (Dead brake on 2nd)	15000	9.246	283.6 0.633	143.1	107.7	0.27263	2.053		2.4	109.8	221.1	225.0
500 @ 30	15,000	9.246	283 0.616	143.5	108	0.26795	2.018		2.4	110.1	218.	222.1
250 @ 18 / 500 @ 30	19,450	11.99	367 0.666	155.5	108.5	0.36758	2.618		2.62	110.1	288.	291.
250 @ 43.5 / 500 @ 30	26,375	16.26	441.8 0.652	185.2	114	0.47341	3.565		3.8	112.6	406.5	409.
250 @ 30 / 500 @ 50	32,500	20.04	591.2 0.69	181.6	112	0.63095	4.751		4.8	114.8	532.	555.
500 @ 50 / 250 @ 64	41,000	25.28	743.8 0.722	163.2	109	0.79070	5.952		6.0	115	649	685.
250 @ 60 / 500 @ 50	60,000	36.99	1078 0.755	155.8	116.5	1.02027	7.686		7.7	120.2	925.	984.
250 @ 55 / 500 @ 50	58,250	35.92	1045.5 0.692	240.5	116	1.05553	7.798		7.8	120.8	940.	960.6

$$\frac{I}{4} = \int_a^Y \frac{dy}{y}\left\{\sqrt{X^2+y^2} - \sqrt{a^2+y^2} + y\log_e\frac{\sqrt{X^2+y^2}-X}{X} - y\log_e\frac{\sqrt{a^2+y^2}-y}{a}\right\}$$

$$\frac{I}{4} = \int_a^Y \frac{\sqrt{X^2+y^2}}{y}\,dy - \int_a^Y \frac{\sqrt{a^2+y^2}}{y}\,dy + \int_a^Y \log_e\frac{\sqrt{X^2+y^2}-y}{X}\,dy - \int_a^Y \log_e\frac{\sqrt{a^2+y^2}-y}{a}\,dy$$

$$= \quad A \quad - B \quad + \quad C \quad - \quad D$$

$$A = \int_a^Y \frac{\sqrt{X^2+y^2}}{y}\,dy = \int_a^Y \frac{X^2+y^2}{y\sqrt{X^2+y^2}}\,dy$$

$$= X^2\int_a^Y \frac{dy}{y\sqrt{X^2+y^2}} + \int_a^Y \frac{y\,dy}{\sqrt{X^2+y^2}}$$

$$= \frac{X^2}{X}\left[\log_e\frac{\sqrt{X^2+y^2}-X}{y}\right]_a^Y + \left[\sqrt{X^2+y^2}\right]_a^Y$$

$$= X\left\{\log_e\frac{\sqrt{X^2+Y^2}-X}{Y} - \log_e\frac{\sqrt{X^2+a^2}-X}{a}\right\} + \left\{\sqrt{X^2+Y^2} - \sqrt{X^2+a^2}\right\}$$

$$B = a\left\{\log_e\frac{\sqrt{a^2+Y^2}-a}{Y} - \log_e\frac{\sqrt{a^2+a^2}-a}{a}\right\} + \left\{\sqrt{a^2+Y^2} - \sqrt{2a^2}\right\}$$

$$A = X\left\{\log_e\frac{a\{\sqrt{X^2+Y^2}-X\}}{Y\{\sqrt{X^2+a^2}-X\}}\right\} + \sqrt{X^2+Y^2} - \sqrt{X^2+a^2}$$

$$B = a\left[\log_e\frac{a\{\sqrt{a^2+Y^2}-a\}}{Y\{\sqrt{2a^2}-a\}}\right] + \sqrt{a^2+Y^2} - \sqrt{2a^2}$$

$$C = \int_a^Y \log_e\frac{\sqrt{X^2+y^2}-y}{X}\,dy$$

$$= \left[\int y\log_e\frac{\sqrt{X^2+y^2}-y}{X}\right]_a^Y + \int_a^Y \frac{y\,dy}{\sqrt{X^2+y^2}}$$

$$= Y\log_e\frac{\sqrt{X^2+Y^2}-Y}{X} - a\log_e\frac{\sqrt{X^2+a^2}-a}{X} + \sqrt{X^2+Y^2} - \sqrt{X^2+a^2}$$

$$D = Y\log_e\frac{\sqrt{a^2+Y^2}-Y}{a} - a\log_e\frac{\sqrt{2a^2}-a}{a} + \sqrt{a^2+Y^2} - \sqrt{2a^2}$$

$$\therefore \frac{I}{4} = X\left\{\log_e\frac{a\{\sqrt{X^2+Y^2}-X\}}{Y\{\sqrt{X^2+a^2}-X\}}\right\} + \sqrt{X^2+Y^2} - \sqrt{X^2+a^2} - a\left\{\log_e\frac{a\{\sqrt{a^2+Y^2}-a\}}{Y\{\sqrt{2a^2}-a\}}\right\} - \sqrt{2a^2+Y^2} - \sqrt{2a^2}$$

$$+ Y\log_e\frac{\sqrt{X^2+Y^2}-Y}{X} - a\log_e\frac{\sqrt{X^2+a^2}-a}{X} + \sqrt{X^2+Y^2} - \sqrt{X^2+a^2}$$

$$- Y\log_e\frac{\sqrt{a^2+Y^2}-Y}{a} - a\log_e\frac{\sqrt{2a^2}-a}{a} + \sqrt{a^2+Y^2} - \sqrt{2a^2}$$

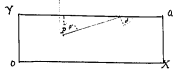
Let $\sqrt{X^2+Y^2} = \mathcal{D}$, $\sqrt{a^2+Y^2} = \mathcal{Y}$, $\sqrt{a^2+X^2} = \mathcal{X}$

$$\frac{I}{4} = X\left\{\log_e\frac{a(\mathcal{D}-X)}{Y(\mathcal{X}-X)}\right\} + \mathcal{D} - \mathcal{X} - a\left\{\log_e\frac{a(\mathcal{Y}-a)}{Y\sqrt{2}(\sqrt{2}-1)}\right\} - \mathcal{Y} - a\sqrt{2}$$

$$+ Y\left\{\log_e\frac{a(\mathcal{D}-Y)}{X(\mathcal{Y}-Y)}\right\} + \mathcal{D} - \mathcal{X} - a\left\{\log_e\frac{a(\mathcal{X}-a)}{X\sqrt{2}(\sqrt{2}-1)}\right\} - \mathcal{Y} - a\sqrt{2}$$

$$= X\log_e\frac{a(\mathcal{D}-X)}{Y(\mathcal{X}-X)} + Y\log_e\frac{a(\mathcal{D}-Y)}{X(\mathcal{Y}-Y)} - a\left\{\log_e\frac{\mathcal{Y}-a}{Y(\sqrt{2}-1)} + \log_e\frac{\mathcal{X}-a}{X(\sqrt{2}-1)}\right\} + 2\mathcal{D} - 2\mathcal{X} - 2\mathcal{Y} - 2a\sqrt{2}$$

On the Inductance and field in a filamentary rectangle. (22)



Let OXaY be the rectangle. Consider a point P whose coordinates are x, y. The force at P due to an element dx in Ya is for unit current in Ya

$$df = \frac{dx\,\cos\theta}{(x-a)^2+(y-b)^2} = \frac{dx\,(Y-b)}{\{(x-a)^2+(Y-b)^2\}^{\frac{3}{2}}} \quad \text{- - - - - - - - (1)}$$

$$f = (Y-b)\int_0^X \frac{dx}{\{(x-a)^2+(Y-b)^2\}^{\frac{3}{2}}} \quad \text{- - - - - - - - (2)}$$

The force at P due to an element dy in OY is similarly

$$f = a\int_0^Y \frac{dy}{\{a^2+(y-b)^2\}^{\frac{3}{2}}} \quad \text{- - - - - - - - (3)}$$

From OX also

$$f = b\int_0^X \frac{dx}{\{(X-a)^2+b^2\}^{\frac{3}{2}}} \quad \text{- - - - - - - - (4)}$$

and from aX

$$f = (X-a)\int_0^Y \frac{dy}{\{(X-a)^2+(y-b)^2\}^{\frac{3}{2}}} \quad \text{- - - - - - - - (5)}$$

Let $(X-a) = \xi$ Let $(Y-b) = \eta$

$$\therefore F = (Y-b)\int_0^X \frac{dx}{\{(x-a)^2+(Y-b)^2\}^{\frac{3}{2}}} + b\int_0^X \frac{dx}{\{(X-a)^2+b^2\}^{\frac{3}{2}}} + a\int_0^Y \frac{dy}{\{a^2+(y-b)^2\}^{\frac{3}{2}}} + (X-a)\int_0^Y \frac{dy}{\{(X-a)^2+(y-b)^2\}^{\frac{3}{2}}} \quad (6)$$

$$= \frac{1}{\eta}\left\{\frac{\xi}{\sqrt{\xi^2+\eta^2}} + \frac{a}{\sqrt{a^2+\eta^2}}\right\} + \frac{1}{a}\left\{\frac{\eta}{\sqrt{\eta^2+a^2}} + \frac{b}{\sqrt{a^2+b^2}}\right\} + \frac{1}{b}\left\{\frac{\xi}{\sqrt{\xi^2+b^2}} + \frac{a}{\sqrt{a^2+b^2}}\right\} + \frac{1}{\xi}\left\{\frac{\eta}{\sqrt{\xi^2+\eta^2}} + \frac{b}{\sqrt{\xi^2+b^2}}\right\} \quad (7)$$

$$= \frac{1}{\eta}\left\{\frac{\xi}{\sqrt{\xi^2+\eta^2}} + \frac{a}{\sqrt{a^2+\eta^2}}\right\} + \frac{1}{a}\left\{\frac{\eta}{\sqrt{\eta^2+a^2}} + \frac{b}{\sqrt{a^2+b^2}}\right\} + \frac{1}{b}\left\{\frac{\xi}{\sqrt{\xi^2+b^2}} + \frac{a}{\sqrt{a^2+b^2}}\right\} + \frac{1}{\xi}\left\{\frac{\eta}{\sqrt{\xi^2+\eta^2}} + \frac{b}{\sqrt{\xi^2+b^2}}\right\} \quad (8)$$

$$= \frac{1}{\sqrt{\xi^2+\eta^2}}\left\{\frac{\xi}{\eta} + \frac{\eta}{\xi}\right\} + \frac{1}{\sqrt{a^2+b^2}}\left\{\frac{b}{a} + \frac{a}{b}\right\} + \frac{1}{\sqrt{a^2+\eta^2}}\left\{\frac{a}{\eta} + \frac{\eta}{a}\right\} + \frac{1}{\sqrt{\xi^2+b^2}}\left\{\frac{\xi}{b} + \frac{b}{\xi}\right\} \quad (9)$$

$$= \frac{\sqrt{\xi^2+\eta^2}}{\xi\eta} + \frac{\sqrt{a^2+b^2}}{ab} + \frac{\sqrt{a^2+\eta^2}}{a\eta} + \frac{\sqrt{\xi^2+b^2}}{\xi b} \quad \text{- - - - - - - - (9)}$$

$$= \frac{\sqrt{\{(X-a)^2+(Y-b)^2\}}}{(X-a)(Y-b)} + \frac{\sqrt{\{a^2+b^2\}}}{a.b} + \frac{\sqrt{\{a^2+(Y-b)^2\}}}{a(Y-b)} + \frac{\sqrt{\{(X-a)^2+b^2\}}}{(X-a)b} \quad (10)$$

and for any position of P whose coordinates may be x .y.

$$F = \frac{\sqrt{\{(X-x)^2+(Y-y)^2\}}}{(X-x)(Y-y)} + \frac{\sqrt{(x^2+y^2)}}{xy} + \frac{\sqrt{\{x^2+(Y-y)^2\}}}{x(Y-y)} + \frac{\sqrt{\{(X-x)^2+y^2\}}}{(X-x)y} \quad (11)$$

$$\therefore I = \int_0^X\int_0^Y \frac{\sqrt{\{(X-x)^2+(Y-y)^2\}}}{(X-x)(Y-y)}\,dx\,dy + \int_0^X\int_0^Y \frac{\sqrt{(x^2+y^2)}}{xy}\,dx\,dy + \int_0^X\int_0^Y \frac{\sqrt{\{x^2+(Y-y)^2\}}}{x(Y-y)}\,dx\,dy + \int_0^X\int_0^Y \frac{\sqrt{\{(X-x)^2+y^2\}}}{(X-x)y}\,dx\,dy \quad (12)$$

Numerically, since each corner is taken in turn as origin of coordinates

$$I = 4\int_a^X\int_a^Y \frac{\sqrt{x^2+y^2}}{xy}\,dx\,dy.$$

The integration is taken from the lower limit a in each case a being not 0

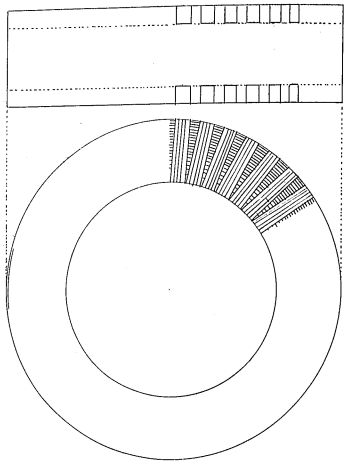
$$I = 4\int_a^Y \frac{dy}{y}\int_a^X \frac{\sqrt{x^2+y^2}}{x}\,dx$$

$$= 4\int_a^Y \frac{dy}{y}\left\{\int \frac{x^2+y^2}{x\sqrt{x^2+y^2}}\,dx\right\}$$

$$= 4\int_a^Y \frac{dy}{y}\left\{\int \frac{x\,dx}{\sqrt{y^2+x^2}} + \int \frac{y^2\,dx}{x\sqrt{y^2+x^2}}\right\}$$

$$= 4\int_a^Y \frac{dy}{y}\left\{\left[\sqrt{y^2+x^2}\right]_a^X + \frac{y^2}{y}\left[\log_e\frac{\sqrt{y^2+x^2}-y}{x}\right]_a^X\right\}$$

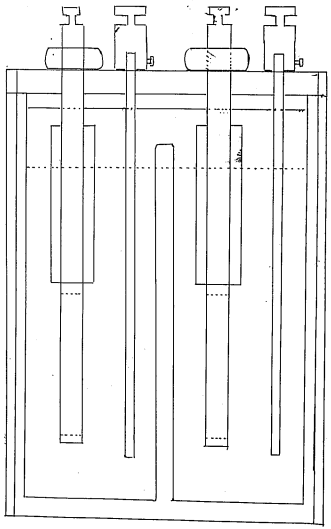
continued on opposite page



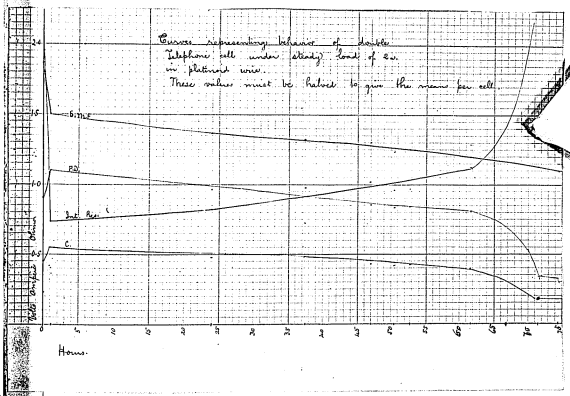
½ Armature Plan and Projection.

Determination of the best Dimensions for a 2½ H.P. Edison Small Motor to be wound for 500 250 and 125 volts.

Bipolar construction.
120 volts.
2000 Watts delivery.
80% commercial efficiency of armature at full load.
95% electrical " " " " " "
2500 Watts intake at full load.
20.8 amperes intake " " "
6 volts drop in arm. " "
0.2885 = resistance of armature not including platinoid (warm).
1500 rpm or 25 r.p.s. speed of armature.
$\phi w = 1.2 \times 10^{10}$ $\therefore \phi w = 4.8 \times 10^{8}$
For the 800 watt motor, $\phi = 300{,}000$. Consequently for 2000 watts,
$\phi = 3.0 \times 10^{5} \times \left(\frac{2000}{800}\right)^{\frac{2}{3}} = 3.0 \times 10^{5} \times 1.84 = 552{,}000$
$w = 872$ from this value of ϕ. and $w/42 = 20.8$ say 20.
$w = 840$ and revising with this value of w
$\phi = 5.714 \times 10^{5}$ useful flux.
$\phi = 14{,}500$
$2b^2 = 39.41$ sq. cms. $= 6.11$ sq. in. $= 3.055$ sq. in for b^2
$b = 1.75''$. 4.45 cms
+ for the 800 watt motor is $4.5''$. for this $4.5\left(\frac{2000}{800}\right)^{\frac{1}{3}} = 1.357 \times 4.5 = 6''$ 15.24 cm
R " " " " " " " " $7\left(\frac{2000}{800}\right)^{\frac{1}{3}} = 1.357 \times 7.0 = 9.5''$ 24.13
Internal circumference $= 18.85''$ 47.88 cms $\div 4.2 = 0.4449''$ 1.114 cms.
External " $= 29.84''$ 75.80 " $= 0.711''$ 1.805.
Area of external circle 70.882 sq. in. 457 sq. cms
" " internal " 28.274 " " 181.5 " "
" " annulus 42.61 " " 275.5 " "
Mean length of one armature turn $8'' = 0.667'$
Length of wire on " $840 \times 0.667 = 560'$
Equivalent length for resistance 140'
Resistance per foot $0.2885/140 = 0.002061\,\omega$ $= \#$ 12 B&S. 0.0808"
Covered diameter $0.081 + 0.015 = 0.096''$
Width of groove $4 \times 0.096 + 0.020 = 0.404''$
" " wall at top $0.4449 - 0.404 = 0.045''$, at periphery $0.711 - 0.4044 = 0.307$
Depth " groove $5 \times 0.096 + 0.020 = 0.500''$. 1.27 cms
Width " armature $1.75'' + 0.5'' + 0.5'' = 2.75''$ = 6.99 cms
Area of each groove on surface $0.404'' \times 1.75 = 0.707$ sq. in. 4.56 sq. cms
Total area of annulus on one side occupied by grooves $= 29.7$ sq. in. 191.6 " "
" " " " " " " " teeth $= 12.9$ " " 83.2 " "
Area on the surface of each tooth 0.307 " " 1.98 " "
Teeth active on one side $42 - 12 = 30$.
" under each pole 30.
Plan area $30 \times 1.98 = 59.4$ sq. cms.
Induction density (mean) in teeth $571{,}000 \div 59.4 = 9620$.
Peripheral velocity of armature $75.8 \times 25 = 1895$ cms per sec. $2.49 \times 1500 = 3700$ fpm
Volume of armature core $275.5 \times 7 = 1928.5$ c.c.
Reduction for groove $191.6 \times 1.27 \times 2 = 487$ c.c.
Reduced volume of core 1441.5 c.c.
" mass of core @ sp. g. of 7.5 = 10,811 gms. = 23.8 lbs.
Flux estimated through core centre 1,143,000 $\mathfrak{B} = 13{,}000$ area = 88 sq. cms
Diameter 10.6 cms. = 4.25"



Full size section of cell. Breadth of cell is equal in both directions, so that the plan of the cell is square.
500 c.c. of solution 1·25 sp.g. in each compartment
Weight of CuO. plates about 107 gm. Weight of copper frame 90 gm
Zn " " 92 "



Test of some switches for carrying capacity

Seven switches were received from the Engineering Department for test.

No 1.	bipolar double break switch	marked for	120 lamps
2	"	"	60 "
3	"	"	30 "
4	"	"	15 "
5	"	"	10 "
6	single "	"	— "
7	"	3-way "	— "

As regards the sparking at the brushes, no 1 will break a simple non-inductant lamp circuit of 110 V. no. 2 nearly as much, while even the 10 light switch will break 40 safely. The limiting carrying capacity is therefore determined by the heat generated in the apparatus. The limit of temperature elevation selected was 15° C. above normal, in this instance from 20° to 35° generally.

Under these conditions

# 1	carried	75 amp. or @ 0·1435	172 lamps
# 2	"	38 "	87 "
# 3	"	24 "	55 "
# 4	"	18 "	41 "
# 5	"	15 "	34·5 "
# 6	"	10 "	23 "

Recommended to the Engineer-in-Chief that the

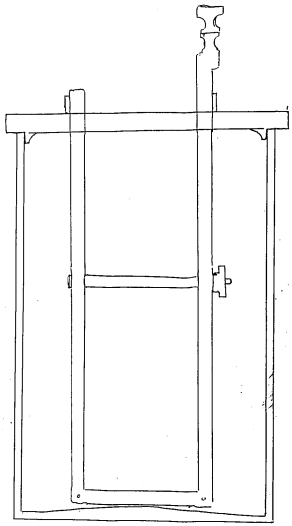
# 1	or present	120 lt switch	be used for 160 lts
# 2	"	60 "	" " 80 "
# 3	"	30 "	" " 40 "
# 4	"	15 "	" " 30 "
# 5	"	10 "	" " 20 "
# 6	"	3 "	" " 10 " or less

Test of a double telephone Edison-Lalande cell in a porcelain jar

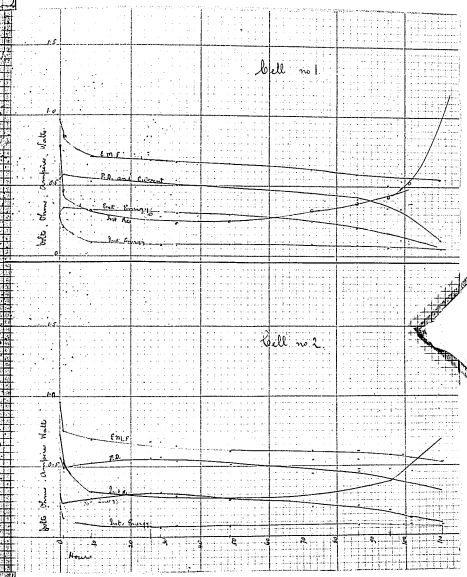
Date	Time	Hrs from start	EMF	PD	Drop	Int. rest	Current	C²	Int. R.	Int. Drop volts	Ext. energy watts	Mean c.	Ex. Wt.	Amp. Wt.
3rd Apr.	12·00	0	1·500	0·966	1·034	1ω	1·034							
4th	9·30	0	1·460	0·900	0·960	2ω	0·480	1·228	2·13ω	0·49	0·456			
"	10·45	1·25	1·390	1·100	0·40	"	0·500	0·3025	0·73	0·22	0·60	0·515	1·25	0·644
4th	9·20	24	1·362	0·966	0·396	"	0·483	0·2333	0·82	0·19	0·467	0·517	22·75	11·76
"	23·00	37·5	1·320	0·972	0·348	"	0·486	0·2362	0·72	0·17	0·472	0·485	13·5	6·55
5th	8·30	47	1·292	0·854	0·444	"	0·427	0·1823	1·01ω	0·19	0·365	0·456	9·5	4·33
"	12·0	50·5	1·234	0·824	0·400	"	0·417	0·1739	0·96	0·17	0·348	0·422	3·5	1·48
"	14·15	52·75	1·230	0·842	0·408	"	0·421	0·1772	0·97	0·17	0·354	0·419	2·25	0·943
"	23·15	61·75	1·258	0·806	0·452	"	0·403	0·1624	1·12	0·18	0·325	0·412	9·0	3·70
16 7th	9·0	71·5	1·124	0·334	0·790	"	0·167	0·0279	4·73	0·13	0·058	0·285	9·75	2·78
11	12·0	74·5	1·120	0·322	0·798	"	0·161	0·0259	4·96	0·13	0·052	0·162	3·0	0·49
													74·40	32·67

15	Weight of zinc plates	before	lost	#1	82·67	#2 80·65
		after	"	#1	43·37	#2 40·93
13					39·30	39·72
				Mean	39·51	

Calculated loss 39·6 gm.



Section of cell full size



Test of Edison-Lalande Telephone cells. 3rd to 6th apr.

Two of these cells were set up with NaHO solution of density 1.26.
The weight of the zinc plate in #1 was 85.71 gms. Copper oxide 103.1 gms
" " " " " #2 " 83.7 " " 93.5 "

The cells were set to work independently upon 1w.

No. of Obs.	Date	Time from start	EMF	PD	Drop in cell	Ext. R.	Current	C^2	Ext. energy	R. of cell	Int. energy	Mean amp.	Amp. Hrs.	Amp. Hrs.
1	3rd apr. 9.0	0	0.966	0.544	0.422	1w	0.5044	0.296	0.296	0.776	0.229			
2	9.40	0.67	0.940	0.576	0.264		0.576	0.332	0.332	0.458	0.152	0.560	0.67	0.37
	17.50	8.83	0.704	0.528	0.176		0.528	0.279	0.279	0.333	0.093	0.552	8.13	4.49
	3rd 10.50	25.5	0.678	0.524	0.154		0.524	0.275	0.275	0.294	0.081	0.526	17.0	8.94
2	13.20	28.3	0.672	0.548	0.124		0.548	0.300	0.300	0.226	0.068	0.524	2.5	1.32
6	17.50	32.8	0.666	0.534	0.132		0.534	0.285	0.285	0.247	0.071	0.541	4.5	2.44
7	4th 9.30	48.5	0.654	0.492	0.162		0.492	0.242	0.242	0.329	0.080	0.513	15.67	8.04
8	5th 9.30	72.5	0.614	0.448	0.166		0.448	0.201	0.201	0.375	0.075	0.470	24.	11.28
9	23.0	86.0	0.588	0.416	0.172		0.408	0.166	0.166	0.422	0.070	0.428	13.5	5.78
10	6th 8.30	95.5	0.588	0.340	0.168		0.340	0.116	0.116	0.494	0.057	0.374	9.5	3.55
11	12.0	99	0.536	0.340	0.196		0.340	0.116	0.116	0.577	0.067	0.340	3.5	1.19
12	16.15	101.3	0.562	0.370	0.192		0.370	0.137	0.137	0.524	0.072	0.355	2.25	0.80
13	23.15	110.3	0.550	0.110	0.440		0.110	0.0121	0.0121	4.00	0.048	0.240	9.1	2.16
													119.23	50.86

Cell No 2.

No. of Obs.	Date	Time from start	E.M.F.	P.D.	Drop in cell	Ext. R.	Current	C^2	Ext. Energy	R. of cell	Int. Energy	Mean amp.	Amp. Hrs.	Amp. Hrs.
1	3rd 9.0	0	0.96	0.556	0.404	1w	0.556	0.309	0.309	0.727	0.225			
2	40	0.67	0.760	0.496	0.264	-	0.496	0.246	0.246	0.532	0.131	0.526	0.67	0.35
3	17.50	9.0	0.692	0.524	0.168	-	0.524	0.275	0.275	0.321	0.088	0.510	8.13	4.15
4	4th 10.50	25.5	0.694	0.558	0.136	-	0.558	0.311	0.311	0.243	0.076	0.541	17.0	9.20
5	13.20	28.5	0.678	0.562	0.116	-	0.562	0.316	0.316	0.206	0.065	0.560	2.5	1.40
6	17.50	33.	0.674	0.536	0.138	-	0.536	0.287	0.287	0.257	0.074	0.549	4.5	2.47
7	5th 9.30	48.5	0.642	0.508	0.134	-	0.508	0.258	0.258	0.264	0.068	0.522	15.67	8.18
8	6th 9.30	72.5	0.612	0.448	0.164	-	0.448	0.201	0.201	0.366	0.074	0.478	24.0	11.47
9	23.00	86.	0.604	0.456	0.148	-	0.456	0.208	0.208	0.324	0.068	0.452	13.5	6.10
10	7th 9.30	95.5	0.570	0.416	0.154	-	0.416	0.173	0.173	0.370	0.064	0.436	9.5	4.14
11	12.0	99	0.570	0.370	0.20	-	0.370	0.137	0.137	0.540	0.074	0.393	3.5	1.38
12	16.15	101.3	0.550	0.358	0.192	-	0.358	0.128	0.128	0.536	0.069	0.364	2.25	0.82
13	23.15	110.3	0.526	0.310	0.216	-	0.310	0.0961	0.0961	0.697	0.067	0.324	7.0	2.01
														52.67

Density of solution after test 1.35.
Weight of zinc No 1. 22.92 gms. No 2. 18.02 gms (No 2 broke off in center between obs. nos. 10 and 11.
Cu O plates No 2 90 gms No 1. 102.

50.36 × 1.212 = 61.05 gms. Calculated consumption in #1 cell actual loss 62.89 excess 1.84
52.67 × 1.212 = 63.88 " " " " #2 " 65.68 1.80

There seemed to be about 10% by estimation of Cu O left in the negative plates.

The cells holds about 600 c.c. of solution.

Nucleus of a dynamical theory of electricity 7th April 91.

The jolting of rather dissimilar molecules, usually occurring at the bounding surfaces of bodies in contact, either in virtue of the dissimilarity of structure, or more probably in virtue of a more dissimilarity of dynamical relationship sets up a vortical motion in themselves and in the ether between them. Motion in order to be but energy must be rectilinear. Vortical motion is electrical energy. The mere diffuence in motion due to difference of temperature will on clashing produce a disturbance whose resultant will be vortical motion, hence thermo-electricity. Vortical motion once set up is likely to continue indefinitely. In uniform activity it produces no phenomena beyond dynamical stresses in the media it traverses.

The establishment of vortical motion in any medium requires an expenditure of energy. The reactive forces or inertia stresses brought into activity and overcome by the vortex forming force is magnetic force, and the magnetic force is thus always proportional to the vortical acceleration. In a non-conducting medium the vortices are established once for all by electric force, that is by communication of the vortex motion of superficial molecules to the intervening medium. The production of the vortices in the medium sets up a momentary reaction or magnetic field but that is all. If however the medium be conducting, the vortices are absorbed in its substance the molecules receiving the motion in the form of oscillations. Their nature and structure dynamically permits of this. The vortex forming force continues in activity and the reaction or line rate of vortical development, sustains in the medium a permanent magnetic field in line radiating from the conductor and the reactionary field sets up movement also vortical but in the opposite sense.

These reactionary forces that are generated by wave impulses themselves constitute an antithetical vortex motion. The rate of development of the reactionary vortices, for precisely converse reasons dynamically react upon the conductor and generate a reverse current in it. Or reaching other conductors their rate of change sets up in them reactionary vortices which are of the first kind (current) in them, thus explaining electrodynamic induction.

Electrostatic forces are purely vortical motion forces

Electromagnetic forces are reactionary vortical forces

If this theory is true, the rapid rotation of a non-conducting liquid in a non conducting (glass say) tube might be expected to develop some feeble magnetic action in its neighborhood, during starting and stopping, but not during steady running.

Particulars of Edison 100 Kilo Watt Multipolar Dynamo.

150 volts, 666 amperes, 172 revolutions.

ARMATURE.

Outside diameter,	66"
Inside diameter,	57"
Width,	12-3/8"

Body to contain 2200 lbs. of #21 B.W.G. oxidized iron wire.

Armature winding in square bars of 56000 square mils cross section, 944 turns all around, or 118 turns per pole.

Total resistance of armature (eight sections in multiple arc) 0.0059 ohms at 0° C.; 0.00755 at 70° C.

Drop in armature at full load, 5 volts. Watts lost in armature, 3390.

MAGNETS.

Diameter of Cores,	12"
Length,	16-1/2"
Bore of Field,	67-3/16"

Field winding, 335 pounds of #12 B.W.G. per core, 2680 lbs. total. Two cores connected in series, four sets on multiple arc.

Resistance per core, cold,	7.6 ohms
Total resistance of shunt, cold,	3.8 ohms.

DATA OF CALCULATION.

Total useful flux,	22,900,000 lines,
" " through armature,	2,860,000 lines,
Intensity in armature,	8,000 lines

Flux through cores (leakage coefficient calculated 1.55)

	4,433,000 lines
Intensity in cores,	6,200 lines

Results of preliminary tests on January 31st, 1891.

Speed, 176 revolutions

Maximum voltage obtained at no load, field resistance all out, 165 volts, with 39 amperes in the shunt as exciting current.

The machine was placed upon an unsteady foundation and consequently could not be loaded up to full capacity. Load was part-

ly on the shop light circuit, and partly on an iron wire resistance. The following readings show the increase of E.M.F. with decreasing load:-

Current in Main Circuit Amperes	E.M.F. on Brushes Volts	Current in Field Amperes
270	128	30.8
235	130	31.2
205	135	32.4
185	137	33
160	140	33.6
120	142	34
95	142	34
75	143	34.4
58	146	35
30	150	36

During the variation of load no movement of the brushes was required and no sign of sparking was noticed on the brushes.

With the load of 128 volts and 270 amperes, the machine was run for one hour and forty minutes: the increase of temperature on the armature after this time was 22° C.

For a short time, a load of 340 amperes was put on the machine, but it had to be taken off on account of the armature striking against the field. Even with this load no movement of the brushes was necessary.

NOTE. The armature body No 1, which was under test, contains but 1450 lbs. of oxidized iron wire of a small gauge (#24 B.W.G.) There is another arma finished, which contains 2212 lbs. of iron wire of a larger gauge (#21 B.W.G.) and which will no doubt give far better results.

Schenectady Works,
March 14th, 1891

$$0.00953 \times \frac{10650 + 2672}{2672} = \frac{0.00783 \times 13322}{2672} = 0.00893 \text{ ?}$$

$$0.10 \times 1.00042 = \frac{0.100042 \times 2672}{2672} = 0.02912 \text{ reliable.}$$

$$0.02912 - x : x :: 2682x : 2672$$

$$2682x = -2672x + 2672 \times 0.02912$$

$$5356x = 2672 \times 0.02912$$

$$x = 0.02450 \text{ lower half}$$

$$1 - x = 0.02462 \text{ upper half.}$$

12th. Apr. 91

. C. Vanderson Esq.

Engineer-in-Chief

Edison General Electric Co.

New York.

ear Sir,-

he following are the results of our tests on the sample of licon-bronze trolley wire from Roonton N. J., referred n your letter of the 9th. inst.

ngth # 4 [illegible] Mean diameter 0.239"

Specific gravity 8.85.

eight per foot 0.1716 lbs. per mile 906 lbs.

nductivity 41.7 % of Matthiessen's standard hard drawn copper at temperature of test (19° C.)

Resistance per foot at 24° C. 0.00048 ohm. per mile 2.374.

Tensile strength 8200 lbs. weight(no appreciable extension by any stress under 5000 lbs.) for 21,100 lbs. per s[illegible]

Ductility [illegible] twists in twelve inches.

Full particulars of tests can be supplied on demand.

Yours fait[illegible]lly,

Consulting Electrician.

1.04.9/2.

Tests of a sample of Trolley-Wire Silicon-Bronze manufactured at Boonton N. J. 14th Apr. 91.

[illegible] 100 feet of this wire was received on the 14th Apr. see letter of 9th from [illegible] gage measurements.

A length of about 75 feet was stretched along the floor, and the gage was taken at every 3 feet as follows:— Brown + Sharpe Micrometer

2	0.2939																								
3		0.2937																							
4			0.2935																						
5				0.2938																					
6					0.2937																				
7						0.2901																			
8							0.2934																		
9								0.2933																	
10									0.2930																
11										0.2934															
12											0.2932														
13												0.2931													
14													0.2926												
15														0.2930											
16															0.2933										
17																0.2934									
18																	0.2930								
19																		0.2933							
20																			0.2937						
21																				0.2938					
22																					0.2936				
23																						0.2934			
24																							0.2943		
																								19	
																								Mean 0.23939	

Mean diameter 0.23939" = 0.6081 cm.
" area 0.04502 □" = 0.2903 sq. cm.

Weight. 2. length of 273.0 cms weighed 1 lb. 453.6
" 8 oz 226.8
255 grs 16.5 6969 grs

" for cm = 2.553 grs.
" " c.c. = 8.796 "
" " foot = 77.8 " = 0.1716 lb.
" " mile = 409,800 " = 905.8 lbs.

Sp. g: by direct measurement. Weight of a small sample in air 11.945
" " water 10.607
1.338

Sp. g. 8.926.

Breaking strain by spring dynamometer:—
Two samples ~~[illegible]~~ broke at 3200 lbs. stretching commenced visibly at 3000 lbs. Both gain breaks in center of specimen.
3200 lbs = 1451.5 kgms = 71,080 lbs per □" = 4997 kgms per sq. cm.

Torsion (ductility). Twisted between lathe centers, one end held, other free in line of axis.

Sample	#1	12"	broke at	17 complete twists
	#2	12"	" "	16 "
	#3	12"	" "	13 "

The last sample #3 broke at the clamp and may therefore not be a fair test.

Conductivity. H.I.B. Diff. Galv. 10 w in cit. for balance with E.N. cit.
Res. of each cit 2672 w.
Wire lengths of the trolley wire were measured, and pressure wire attached at the points marked.

No 1.	326.45
" 2	733.95
" 3	1049.28
" 4	1571.25
" 5	2060.55

Preliminary balances. Standard 0.01 w @ 23°C. : Platinoid grid :: 2672 : 2672 + 10
Standard 0.1 w @ 22°C. : grid :: 2672 + 2770 : 2672

Upper half of grid : lower half :: 2672 + 12 : 2672

$1593.5\ (1 + 0.00388 \times 19) =$ $1593.5\ (1 + 0.0737) = 1711$

$1634\ (1 + 0.00388 \times 19) =$ $1634\ (1.0737) = 1754$

$1 + 0.00388 \times 5 =$ $1634\ (1.0194) =$

Ref. No.	Ren[illegible] Tra[illegible]
1	20[illegible]
2	20[illegible]

DATA FOR THE EDISON EXPERIMENTAL LIGHTNING PROTECTOR.

Material's ship-to-jail. Leadfoil 1/2 [illegible] PROTECTOR.

The such strips are rolled up together [illegible] 1" long and [illegible] paraffined paper about 2½" long [illegible] with [illegible] of

Each paper strip is composite, [illegible] and 0.01" thick, sheets of thin tissue paper [illegible] being itself made up of four soaked in molten [illegible] as silver tissue paper.

One leadfoil strip is rolled up with a kerite wire bound within the lead, 0.0[illegible] covered to 0.20", the other leadfoil strip is rolled upon a leaden wire 0.02" diameter. These three electrodes are about 1½" long, and each communicates with one quarter of the condenser. The total area of active surface is 1.5 sq. foot. The exact length of strips used varied with the skill of the operator who rolls them up.

The roll is [illegible] up on a hot [illegible], and is then inserted in a plain zinc tube 6" long, 0.[illegible] int. 0.[illegible] external diameter. The two electrodes project out from each end.

The ends of the tube are then sealed with a composition of asphalt, linseed oil (boiled), and a special powder known as Phonograph powder [illegible] made by the [illegible] Powder Co. of [illegible]. The resulting compound (40% by [illegible] asphalt, 10% of boiled linseed oil, and 10% of [illegible]) makes a high temperature melting point stick well [illegible] normal temperature without softening. Care has been [illegible] taken in pouring it in order to melt the lead wire.

A strip of zinc is soldered on to the tube before the condenser is inserted to serve as a holder by which it may be nailed up to a pole cross-arm.

The tubes then receive a coating of air-dry japan.

They are then tested at a pressure of 1250 volts. They give a spark on discharge after receiving this pressure and are capable of giving a shock if left insulated for more than an hour afterwards.

The mean capacity of [illegible] condensers is 0.01 microfarad with a mean [illegible]

The approximate cost of material used in one [illegible]

[illegible] per foot	3.25 c.
[illegible] of lead wire at 0.75 per lb.	1.5
[illegible] of lead foil at 0.[illegible] per lb.	0.[illegible]
[illegible] of paper at [illegible] per ream	1.2
zinc tube lightning [illegible] at 1d c. per lb.	[illegible]
asphalt composition	1.0 [illegible]
Total	8.75

The best place for one of these arrestors is on the cross-arm of a pole near to the wire it protects and close to the insulator. The [illegible] is connected and preferably below the [illegible] arrestor and the lead wire which should be on the lower end is connected direct to ground, as it goes down the pole, to a ground plate [illegible] 6 meshes or [illegible] pipe. The ground connection should in all cases be as direct as possible. The junction between the ground wire and the wire should be covered with tape and made water-tight.

A common ground wire may serve several arrestors on the same pole.

Trolley wire Tests continued.

[illegible]	Length of Trolleyline	Standard	Res. of Std.	Resistance for balance	L	Ratio	Res. of wire	Res. of wire per cm.	Resistivity	Conductivity $\times \frac{1000}{1728}$	Temp. of wire
1	2600.55	grid	0.04913	1730ω	grid	$\frac{4403}{2672}$	0.02982	1.4475×10^{-5}	4.205×10^{-6}	0.4069	19°C
2	2600.55	5mm half	0.02245	570ω	wire	$\frac{3263}{2672}$	0.02970	1.443	4.192	0.4080	"
7	25	–	–	206ω	grid	$\frac{2878}{2672}$	0.02970	1.4475	4.205	0.4069	"
8	28	–	–	1636ω	"	$\frac{4308}{2672}$	0.01595	1.448	4.206	0.4068	"
13	95	–	–	3478ω	"	$\frac{6150}{2672}$	0.01064	1.4503	4.213	0.4062	"
14	95	0.01ω	0.00983	225ω	wire	$\frac{2897}{2672}$	0.01060	1.4528	4.220	0.4055	"
15	45	–	–	2860ω	0.01ω	$\frac{5532}{2672}$	0.00749	1.456	4.227	0.4047	"

check, compared the wire with a copper rod already used in low case see p. 86. Length of rod between electrodes 273.8 area of section 0.3267. Equivalent length of 0.2905 = 243.5 cm. Balanced against this at 1114.0 cm. of trolley wire – relative conductivity 0.468.

Resistivity @ 19°C. 4.205×10^{-6} Conductivity 0.4069 of Matthiessen's Std at temp 19°
" 0.4147 " " hard copper . . . .

Resistance per cm @19°C. 1.4475×10^{-5} ω = @24°C. 1.476×10^{-5}
" – foot @19°C. 4.412×10^{-6} ω = " 4.497×10^{-6}
" – mile " 2.329 " = 2.374 ω.

On Condenser lightning arrestors.

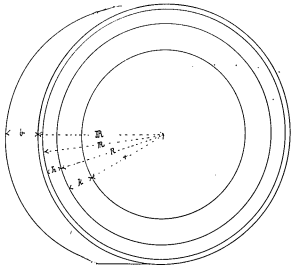
The condensers are made up of two strips of Tinfoil 6" wide and 17" long 0.0015" thick (0.0038 cm.) separated by three sheets of paraffined paper of total thickness 0.01" or 0.025. The surface of condenser is thus 2 (6"×17") = 1.45 sq. ft. = sq. cms. The two sheets are rolled up with a lead wire 0.074" # 15 B.W.G. and kerite wire 0.067" covered to 0.20". separately. The roll is inserted in a zinc tube 9" (22.9) long and 0.88" diam. int. 0.825" int. diameter. Its own length is about 7.5". The two ends of the zinc tube are plugged with a composition of asphalt 0.8 Gilsonite #1 pitch 0.1 and boiled linseed oil 0.1. This makes a high melting point asphalt. The capacity of the condenser is about 0.018 made up with only two thicknesses of paper (silver bacon paper) the condensers break down under 1200 volts. When made up with 4 papers they generally stand 2400. A spark or series of sparks if passed through the condenser from a Holtz machine did not cause the condenser to break down under a subsequent application of 1200 volts.

The approximate cost of material in the condenser is :–

1.5 feet of Kerite wire @ 1.5 ¢ per foot	=	2.25
1.5 " Lead fuse wire @ 0.75 ¢ per lb. = 50 ft of 1 lb. in weight		1.50
3.0 feet of 1 ½ mil Lead foil @ 16 ¢ per lb.	=	0.5
6 × 2.0 = 12' of paper @ $1.00 per ream	=	1.2
Zinc tube 9" @ 18 ¢ per lb. 1/6 lb of 1 lb	=	3.3
Asphalt Composition		1.0 ?
Total material.		9.75

Asphalt @ 9¢ per lb.
Linseed oil @ 60¢ per gal.

Total 10¢ as complete



Let r = internal radius (cms) of core proper
R = external " " " "
R = internal " " winding space
R = external " " armature
b = breadth of core (cms)
h = $(R - R)$ or winding depth
h = $(R - r)$ or core depth
p = number of poles.
g = width of polar gap measured along periphery (cms) = αR
α = coefficient of polar gap.
t = Ratio of both surfaces to periphery of armature at radius R
w = number of wires all round
d = diameter of wire cms
D = covered diameter " "
y = $\frac{D}{2}$
ρ = resistivity of wire AEMU. at working temp.
ϖ = length of one turn round armature cms
σ = resistance of armature between brushes AEMU
B = Mean induction density in both cos. lines per sq.cm
b = " " " " armature core " " "
ϕ = polar useful flux
ψ = armature " " = $\phi/2$
E = EMF generated by armature AEMU.
n = revs per sec of armature.
x = $\frac{R-r}{b}$ = $\frac{h}{b}$
j = coefficient of increase in σ due to winding. now and above $2(K+h+b)$

Revised Formulae for the Determination of Multipolar Motors

$$E = \phi n w \qquad (1)$$

$$\phi = 2 \mathcal{B} b k \qquad (2)$$

$$\sigma = \frac{w \varpi \rho}{p^2 d^2} \qquad (3)$$

$$\varpi = 2(b + k + 2h) \qquad (4)$$

$$w y^2 t = 2 \pi R (1 - t) h \qquad (5)$$

$$2 \pi n R = V \qquad (6)$$

$$b R = s H \qquad (7)$$

$$\text{where } H = (F + c\sigma) \qquad (8)$$

In the problem E, n & p are given
This allows H, and σ to be determined.
V is also to be decided upon, while s is to be calculated from machines of similar type

(a) R is first calculated from (6)
(b) b is then obtained " (7)
(c) $w = \dfrac{\sqrt{\sigma p^2 \pi R h (1-t)}}{\rho y^2 (b + k + 2h)}$ from (3) (4) + (5)
(d) $k = \dfrac{E}{2 \mathcal{B} b n w}$ from (1) + (2)

In (c) R is taken equal to R. t is given a trial value, which must be subsequently examined for mechanical conditions and by the formula

$$t = \frac{\phi}{\mathcal{B} b R \left(\frac{2\pi}{p} - \alpha\right)}$$

y is also estimated and k is given a (preliminary) value which may need revision after (d) has been worked out. If the values for R, b, w, and k as thus determined are consistent, the magnetic circuit has next to be examined

Formulae for the Determination of Multipolar Gramme Ring Motors

$$E = \phi n w \qquad (1)$$

$$\phi = 2 \mathfrak{B} b k \qquad (2)$$

$$= 2 \mathfrak{B} b^2 x \qquad (3)$$

Total polar surface $= b\left(\frac{2\pi \mathfrak{R} - pg}{p}\right) = \frac{b\mathfrak{R}}{p}(2\pi - \alpha p)$

$$= b\mathfrak{R}\left(\frac{2\pi}{p} - \alpha\right)$$

Useful " " $= bt\mathfrak{R}\left(\frac{2\pi}{p} - \alpha\right)$ - - - - - - - - - - (4)

$$\Phi = bt B \mathfrak{R}\left(\frac{2\pi}{p} - \alpha\right) \qquad (5)$$

$$\alpha = \frac{w \varpi \rho}{p^2 d^2}$$

$$\varpi = 2(b + h + 2h)$$

$$w y^2 d^2 = 2\pi \mathfrak{R}(1-t)h$$

$$\therefore \alpha = \frac{2 w^2 (b + h + 2h) \rho y^2}{2 p^2 \pi \mathfrak{R}(1-t)h} \qquad (6)$$

From (1) + (3) $E = 2 \mathfrak{B} b^2 x n w$ - - - - - - - - (7)

(3) + (5) $b = \frac{B t \mathfrak{R}}{2 \mathfrak{B} x}\left(\frac{2\pi}{p} - \alpha\right)$ - - - - - - - - - (8)

$$\therefore E = \frac{1}{2} n w \frac{B^2 t^2 \mathfrak{R}^2 \left(\frac{2\pi}{p} - \alpha\right)^2}{2 \mathfrak{B} x} \qquad (9)$$

$$w = \sqrt{\left\{\frac{\sigma p^2 \pi \mathfrak{R}(1-t)h}{\rho y^2 \{b(1+x) + 2h\}}\right\}} \qquad (10)$$

$$E = \frac{n B^2 t^2 \mathfrak{R}^2 \left(\frac{2\pi}{p} - \alpha\right)^2}{2 \mathfrak{B} x} \sqrt{\left\{\frac{\sigma p^2 \pi (1-t)h}{\rho y^2 \{b(1+x) + 2h\}}\right\}} \qquad (11)$$

$$\mathfrak{R}^2 = \frac{2 \mathfrak{B} x E}{n B^2 t^2 \left(\frac{2\pi}{p} - \alpha\right)^2} \sqrt{\left\{\frac{\rho y^2 \{h(1+\frac{1}{x}) + 2h\}}{\sigma p^2 \pi (1-t)h}\right\}} \qquad (12)$$

We are supposed to know $\mathfrak{B}, E, B\ p\ \alpha\ n\ \rho\ \sigma$.

Further $w = \sqrt{\frac{\sigma p^2 \pi \mathfrak{R}(1-t)h}{\rho y^2 \left[\left(\frac{B t \mathfrak{R}}{2 \mathfrak{B} x}\right)^2 (1+x) + 2h\right]}}$

$$= \sqrt{\frac{\sigma p^2 \pi (1-t) h\, 2 \mathfrak{B} x}{\rho y^2 B t \left(\frac{2\pi}{p} - \alpha\right)(1+x+j)}} \qquad (13)$$

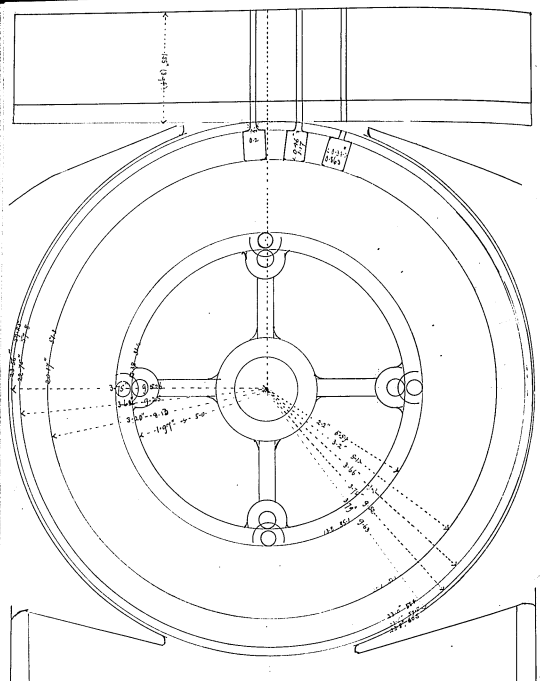
and $\mathfrak{R}^2 = \frac{2 \mathfrak{B} x E}{n B^2 t^2 \left(\frac{2\pi}{p} - \alpha\right)^2} \sqrt{\frac{\rho y^2 B t \left(\frac{2\pi}{p} - \alpha\right)(1+x+j)}{2 \sigma p^2 \pi (1-t) h\, \mathfrak{B} x}} \qquad (14)$

Here x and y are given trial values while t, h, and j are estimated.

This determines $\mathfrak{R}$.

b is then to be found from (8)

w from (13) or (10)



Specification for a 1 HP 120 volt motor.

1800 r.p.m. = 30 r.p.s.

Delivering 800 Watts at 0.90 armature electrical efficiency and 120 v. at motor terminals.

At 0.70 commercial efficiency the ~~current~~ energy in the motor is $\frac{800}{0.7}$ = 1140 watts ÷ 120 = 9.5 ampere. 1.0 × 120 = 120 volts $\frac{120}{9.5}$ = 1.260 hot. = 1.1 v for the armature without platinoid wire.

The cross section of the armature core is 10 sq. cms. of which 0.9 is available for wire = 9 sq. cms. ~~and 0.2×2.3 = 1 sq. cm. reduction for bolt space leaves 8 sq. cms~~ × 18,000 = 153,000 lines say 150,000 or a total flux of 200,000. The number of turns must be 1330 of which the nearest even multiple of 36 is 37.

The mean turn will have a length of 0.6' and 1332 turns = 799.2'

for 1.1 v = $\frac{2.09}{1.1}$ = 1.82' per ohm. @ 100° C = 0.04 Ω = # 18 B.W.G.

covered this wire will be 0.059", and 5 wide = 0.295" + 0.025" = 0.320"

7 wire high = 0.413" + 0.025" = 0.438".

36 grooves, 36 commutator blocks.

Depth of groove 0.44", width 0.320".

Width of walls 0.312" above, 0.24" below. (0.792, + 0.610)

Polar length = Tg 18 of $\frac{19.85}{2}$ = 2.3 × 3.0 = 7.0 sq. cms polar area.

Polar angle $\frac{3.5}{2}$ × 360 = 140°. Gap. angle 40°.

Radial projection, mica 0.010", wire 0.010". clearance 0.020" = 0.040" = 0.1 cm. Polar reluctance $\frac{0.1}{7.0}$ = 0.0014, say 0.015".

Total gap reluctance 0.0030

Breadth of armature 1.25" (3.16)

Total flux allowed for in field magnet 600,000 at density of 15,000 = 40 sq. cms. = 7.14 cms. diam = 2.81".

When the machine was ~~laid~~ laid out for a working drawing, it was found that there was not sufficient room in the interior of the armature for coiling the wire. On this account the int: diameter was increased to 4.40". The cross section of the armature being 1.55 sq. in., the width of the armature core will be 1.55".

The wire used in winding a preliminary model is 0.069" covers to 0.061", and five wide = 0.305" + 0.03" = 0.335"

seven high = 0.427 + 0.030" = 0.457

Each wall will now be $\frac{5.54}{36}$ − 0.863 = 1.622 − 0.863 = 0.759 (0.3") above

and $\frac{5.40}{36}$ − 0.863 = 1.420 − 0.863 = 0.557 (0.22") below

14 walls carry the total flux = 14 × 0.557 × 3.94 = 30.7 sq. cms. an average density of $\frac{300,000}{30.7}$ × $\frac{1}{0.8}$ = $\frac{300,000}{24.56}$ = 12,200.

Length of wire in 35 turns 19 feet. 0.54' per turn.

Surface of armature is 2π (2.63² − 4.4²) + 8π (9.6 + 4) = 2π (92.7 − 16 + 54.4)

2π (131) = 823 sq. cms.

∴ Heat developed in armature will be 100 Watts for foucaults + 9.5² × 1.1 = 90.2 × 1.1 = 99.2 for armature resistance say 200 Watts in all.

The peripheral speed of the motor will be 30 × 2π × 9.6 × 0.9 = 1628 lines

The mean speed ~~mile~~ armature = 60 × 4 × 1628 + 592.4 × 1153 + 100 × 670

= 39,000 + 67,000 + 67,800 = 1,130,000 c.c. per sec: for 200 Watts

= 5650 c.c. per sec: per Watt.

Test of Alternator at Schenectady 13th April

The new armature in this motor has the same dimensions as the previous one, and is wound with copper wire in the same manner but its body is made up of square oxydized iron wire 0.05" × 0.05".

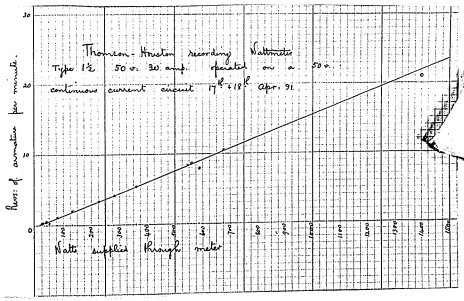
Current was turned on the field at 9.44 am, the machine making 1200 r.p.m. Readings taken with a Cardew voltmeter, multiplying power 1143.

No. of Obs	Amp. in field	Amp. turns on each field coil	MMF on magnet circuit	Cardew volts	Calculated effective flux	Max. EMF on assumption of pure sine	Actual flux in the magnet circuit	Reduction of circuit	Unaffected Maximum flux 16250×10^6	Reduction of air		
1	9	2157	6176	45	514.6	727	4.93×10^6	1.25	4.44×10^6	1.39×10^{-3}		
2	10	2730	6862	50	571.5	898	5.48	1.25	4.93	1.39		
3	11	3003	7550	55	629	880	6.03	1.25	5.49	1.375		
4	12	3276	8234	62	709	1002	6.69	1.24	6.115	1.35		
5	13	3550	8924	68	777	1099	7.15	1.24	6.708	1.33		
6	14	3822	9610	72	823	1164	7.89	1.22	7.104	1.35		
7	15	4094	10290	77	881	1246	8.48	1.22	7.606	1.35		
8	15.5	4231	10630	81	926	1310	8.88	1.20	7.996	1.33		
9	16	4367	10980	87	995	1407	9.54	1.15	8.586	1.28		
10	17	4641	11670	90	1029	1455	9.87	1.18	8.880	1.32		
11	17.5	4777	11990	93	1063	1503	10.20×10^6	1.18	9.174	1.31		
12	18	4914	12350	98	1121	1581	10.75	1.22	9.650	1.28		
13	18.75	5118	12880	106	1212	1714	11.63	1.21	10.460	1.23		

The machine was operated at various loads but at 10.43 the conditions were :-

Obs.	Amp. in field	Amp. turns on each field coil	MMF on magnet circ.	Cardew volts	Calculated effective f.d.	Max. EMF on assumption of pure sine	Useful flux the same	Red. of circuit.	Armature effective in each coil	Armature turns in series	Frequency	Energy measured by lag.	
1	18.25	5090	12800	98	1121	1760	1.075	"	27	35.1	39.34		
2	18.0	4914	12350	90	1029	1616			32.3	42.0	43.20		
3	18.0	4914	12350	93.5	1070	1681			31.6	41.1	44.00		

The pressure on the field was 110 v. so that the res. of the field (warm) was 6.110 (cod 5.75-) At 11.10 one of the main armature bands of phosphor bronze wire (5 turns in each band) burst with a loud report, and the armature expanded until it touched the field. This threw off the belt and hopelessly damaged the armature.


Thomson-Houston recording Wattmeter
Type 1½ 50 v. 30 amp. checked on a 50 v.
continuous current circuit 17th-18th Apr. 91
Flues of armature per minute.
30
20
10
0
Watts supplied through meter
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
6.00
6.50
7.00
7.50
8.00
8.50
9.00
9.50
10.00

Tests of Thompson-Houston Wattmeter 17th April 91.

Two of these instruments were tested marked #34774 and #4817. They are intended for 50-volt alternating-current-work.

The armature of these motors are in series with a resistance and the field are connected across the supply mains. The resistance in circuit with the armature is 3140 in one and 3340 in the other. The resistance of the armature itself is 1400 in one 1370 in the other. The field coils are in series with the load, and have a resistance of 0.01030 in one and 0.01220 in the other. The machine being intended for 50 volts and 30 amperes the drop at full load is about 0.31 to 0.37 volt.

The worm on the armature shaft engages with a wheel of 100 teeth whose pinion has 10, and four similar wheels with disk on them complete the brainwork. Consequently the motor makes one rev. for how per watt. or 1 r.p.m. means 60 watts (approximately 2500 watts per hour)

The copper disk forming the magnetic brake is 13.32 in diam. and 0.163 thick. It weighs 210 gms.

The magnets of which there are three on each disk weigh 440 gms., are 11.3 in total length, 4.5 in total height 3.18 in uniform width 0.68 thick uniformly and have a square field 3.18 × 3.18 with 0.62 perpendicular distance.

The armature has a diameter of 5.75, a height of 3.5, rising in the center to 4.65, and the weight of armature and spindle together is 110 gms. The total weight of the moving mass is therefore 320 gms.

The following observations were made, with three meters in series with their armature directly connected in parallel.

No. of Obs.	No. 4817 Obs.	Amp.	Volts	Watts	R.p.s.	R.p.s./Watts			R.p.s	R.p.s/Watts	No. 34774 Watts R.p.s.	R.p.m.
1	2.16	11.26	49.5	557.3	0.8163	2.9812 × 10⁻³			0.1449	2.6012 × 10⁻³	3245	8.694
2	4.15	21.64	120.5	2608	0.6060	2.324 -			0.625	2.396 -	4174	37.5
3	3.4	17.73	123	2181	0.4525	2.075 -			0.4938	2.265 -	4415	29.63
4	1.56	8.136	72.2	587.5	0.10285	1751 -			0.1325	2.225 -	14994	7.95
5	0.1500	0.782	52	40.67	~~0.006555~~	1613			0.00558	1.613 -	6200	0.3935
6	0.115	0.5996	44	26.38		"			0.003216	0.731 -	13680	0.193
7	~~0.099~~											

#34774 Repetition of Test under more favorable conditions 18th Apr. 91.

No. of Obs.	Obs.	Amp.	Volts	Watts	R.p.s.	R.p.s./Watts	Time	Seconds	R.p.m.				
1	1.047	5.461	51.4	280.5	0.06796	2.424 × 10⁻³	40	588.5	4.078				
2	2.112	11.02	49.6	546.6	0.1394	2.550 × 10⁻³	40	287	8.362				
3	2.812	14.67	46.0	675.0	0.1762	2.611 × 10⁻³	40	227	10.57				
4	1.350	7.04	51.2	360.5	0.08997	2.496 "	40	444.5	5.398				
5	0.825	4.30	52.9	227.5	0.05749	2.382 -	20	369	3.252				
6	0.486	2.535	54.0	136.9	0.03356	2.451 -	10	298	2.014				
7	0.277	1.445	53.6	77.4	0.01773	2.291 -	5	282	1.064				
8	0.129	0.673	54.8	36.9	0.00283	0.7687 -	1	439	0.127				
9	0.090	0.469	55.0	25.8	0		stop		0				

Determination of the best winding for a battery fan motor of 4 cells using the Edison Lalande cells and the worn work of the Edison 1/16 H. P. motor, now at Schenectady

4 cells = 2·8 volts. E.M.F. Allowing electrical efficiency in the circuit for the armature at 0·4 = 1·12 volts generated by armature. The flux in armature = 30,000 and the speed 600 r.p.m. = 10 r.p.s. ∴ be that the number of turns must be $1.12 \times 10^8 / 3.0 \times 10^4 = 373$, say $42 \times 8 = 336$, or $42 \times 9 = 378$.

The winding space in each groove after deducting insulation is 0·22" broad by 0·24" deep. Each wire must therefore be $\frac{0.22}{3} = 0.073"$ diam. covered = 0·060". The nearest is #17 B.W.G. 0·058" and 0·00351 = per foot. Each turn averages about 0·25' so that the length of wire = 99' and its equivalent resistance is $25 \times 0.00351 = 0.088\,\Omega$, with German silver connections this might be increased to 0·1 Ω.

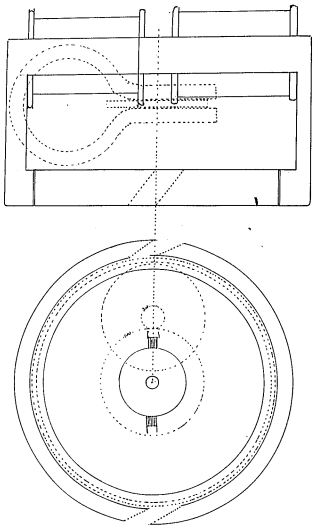
Determination of the dimensions for an Edison Electrolytic Balance Meter for Household purposes.

The area exposed on the surface of one plate in the present standard meter bottle is 1·5 sq. in: on the inside face, and if the sides be added 0·25 (5) = 1·25 more making a total 2·75 sq. in: = 17·74 sq. cms. of active surface at a distance of 0·25" = 0·635 cm: from the opposite plate. The resistance of this arrangement is 2·5 Ω @ 70° F. At ¢8 meter transfers 1 mgm. of zinc for 8 ampere-hrs. = $\frac{8}{0.4}$ = 20 lamp-hrs = 25 ¢. in money value. Such a plate is usually weighed to 5 mgms. and the error is thus less than ¢1·25. Let the limit be now reduced to 10 mgms, and let the current through the meter be increased 3 times, at the same time let the resistance of the meter bottle be reduced 10 times. Let the clearance be 1 cm: then the surface of the cylinder in active use must be $\frac{10 \times 17.74}{0.635} = 279$ sq. cms.

A cylinder 2·5" in diam: will be 6·35 cms. in diam. and 19·95 cms. in circumference = 14·0 cms: long = 5·5" allowing for hole being cut for circulation = 6" long. If the thickness of the cylinder be 3/32" = 0·24 cm. there will be about 70 c.c. of zinc in the whole cylinder. The sp. g. being 7·2 the mass will 504 gms. in solution of 1·11. the weight will be 430 gms. or 1 lb.

With half this thickness of metal namely 3/64" = 0·12 cm. there would be a mass of 250 gms weighing 2/5. It would be possible to float this in such a way that only a weight of any 100 gms was sustained by the scale beam. 150 gms. or 110 c.c. of solution would be displaced. The range of temperature would be from 40° F (4·5° C) to 90° F (32·2° C). The expansion of the solution per °C. is (See Book II p.23) 0·075 % per °C. = 27·7 × 0·075 = 2·07 % for the whole range. The mass of 110 c.c. @ 27·7° C elevation of temp. would be 114·9 gms. That is it would gain 3 gms: in weight owing to this range. This large error would necessitate a correction for temperature.

Half sight section of arc lamp circuit



75 commutator blocks, 150 turns of wire on armature.
Cross section of armature 2·5 x 0·375 = 0·95 sq. cms.
Cross " " field core 5 sq. cms.
Cross " " field polar segment 2·5 x 1·25 = 3·17 sq. cms
1 revolution of the armature raises the rod 4 cms. Pitch radius 1·27 cms.
Copper disk 0·325 cms. thick diameter 7·55. geared with armature 6 L1.
Resistance of armature between brushes 0·2 ω
" " main cct. field 0·02 ω
" " shunt " 320 ω

Resistance of a Pilsener arc lamp series coil 0·155 ω
" " " Sperry) " " " 0·125 ω

Lightning Arrestors for Edison Illuminating Cos.

50 arrestors were received from the Phonograph Works on the 24th April. Of these 11 were lost in testing on 1250 volts, since they broke down under that pressure. Of the remainder, 13 were sent to Scranton Pa, 13 to West Chester Pa and 13 to Piqua O. on the 25th April. Average copy 0·016 ℄ 3 thickness paper

Edison Motor Arc Lamp. 23rd Apr: 91.

This motor arc-lamp was first tried on the 23rd Apr. It has an armature of the dimensions shewn on the opposite page. It has a double field winding. The upper half has four layers of 19 turns (76 in all) of # 10 B.W.G. 0·134" cond: to 0·150" and this in the line circuit. The lower half has 40 layers of 178 turns each (7120 in all) of # 31 B.W.G. 0·010" cond. to 0·015". The resistance of this shunt coil is 360 ω cal. The armature is wound with 150 turns (75 "groups") of # 16 B.W.G. 0·068" cond. to 0·081" in one layer, and the commutator has blocks. The armature is also in the line circuit. The shunt coil was found to preponderate in strength, pulling the arc too short. With about 100 ω added, the arc became very steady and the current 9 ampères @ 54 volts.

Evaporation Experiment 22nd april 91.

A quart glass measure was filled with tap water to the quart mark, and a film of paraffine oil about 0·25 thick added. The area of surface was about 70 sq. cms. The vessel was placed over the boiler, and the temp. of the water became about 41° C. No comparative loss could be detected by the eye after 72 hours.

The experiment was continued until the 28th May, and no change could then be detected in the level.

Resistance of Experimental Car Track 24th Apr.

The experimental low-tension car track is ready as far as the Phonograph Fence, all the rail joints being complete. The following are the results obtained. Short circuit made at different points

No. of Pts	PD at brushes	Amperes	Distance of s.c. along track	Res: of length	Res: from zero point	Res: per foot				
1	4·	850	76 ft	0·00473	0·00195	0·0000262				
2	3.	1100	0	0·00278	0	0				
3	4	900	59 "	0·00444	0·00166	0·0000281				
4	4·25	750	133 "	0·00567	0·00289	0·0000217				
5	4·5	675	191 "	0·00665	0·00387	0·0000202				
6	5	600	264 "	0·00833	0·00555	0·0000210				
7	5	575	301 "	0·00862	0·00584	0·0000187				
8	9	0	–	–	–	–				

Formulæ for determining G.S. corrections for bipolar dynamos.

If c = the res: in ohms of one armature coil
n = " number of coils
t = " res: of the armature between brushes if without g.s.
R = " " " " " " with g.s.
ρ = " " of one g.s. connection

Then $\frac{c+2\rho}{c} = \alpha$ (1)

$\frac{R}{r} = \beta$ (2)

$t = \frac{n}{4}c$ approximately

$R = \frac{n}{4}c + \rho$ if brush rest on 2 + not more than 2 bars always

$\therefore \beta = \frac{\frac{nc}{4} + \rho}{\frac{nc}{4}} = 1 + \frac{4\rho}{nc}$

(1) $\rho = \frac{\alpha c - c}{2} = \frac{c}{2}(\alpha - 1)$

$\beta = 1 + \frac{2(\alpha-1)}{n}$

For 3 bars $\frac{2c + \frac{2c}{3}}{2c} = \alpha$

$\beta = \frac{\frac{nc}{4} + \frac{2c}{3}}{\frac{nc}{4}} = 1 + \frac{8c}{3nc}$

(1) $\rho = \alpha c - c = c(\alpha - 1)$

$\beta = 1 + \frac{8}{3}\frac{\alpha - 1}{n}$

Determination of the dimensions for a G.S. Resistance to carry 200 amperes without overheating at a p.d. of 0.2v.
28th April 91.

The strip will be 3" wide = 7.62 cms, and 0.009" = 0.0229 cm which assume a resistivity of 3.0×10^{-6}.
The resistance of the instrument must be $0.001\,\omega = 10^6$ A.E.M.U.
The res: per cm: will be $\frac{3.0 \times 10^{-6}}{7.62 \times 0.0229} = \frac{3.937 \times 10^{-3}}{0.0229} = 1.7193 \times 10^{-5}$

Allowing 500 eq: cms: per watt and there will be at full load 100 watts = 2000 eq: cms.

$2lw \cdot 7.62 = 2000$ and $\frac{l}{w} \cdot 1.7193 \times 10^{-5} = 10^{-6}$

$lw = 1310.5$ $\therefore \frac{l}{w} = 5.817$

$\therefore l^2 = 1106$ $l = 33.26$

$n = 6$ nearest integer

$l_n = \frac{60}{1.7193} = 28.604 = 11.27''$.

6 plates 12" long 3" wide 0.009" thick in multiple arc.

Particulars of the 10-lt: Sperry Arc Dynamo

Resistance of field @ 16° C. 8.76 ω.
" " armature @ 16° C 8.65 ω.

There are 96 commutator blocks, so that the resistance of one section is $\frac{8.65}{24} = 0.36\,\omega$.

If the ratio α be made 6 with 3 bars under the brush,
$\beta = 1 + \frac{40}{288} = 1.14$, the resistance of the armature will be increased 14 %. and $\rho = 1.8\,\omega$

This represents about 1.25" of #29 B.W.G. 0.013" diam:

With this wire inserted between commutator and armature, about 2000 volt could be obtained from the machine with separately excited field.

There was very little sparking under any condition of lead or load.

On the surface necessary to give an armature in order to enable it to deliver its heat freely.

Without attempting the solution of a very complex problem which would be followed in analyzing the distribution and disengagement of heat from an armature, the following principles may be admitted:—

Let ds be an element of the surface of an armature.
θ be its temperature elevation above surrounding air.
v . its translational velocity
dh . the heat it imparts by convection to the surrounding air.

Then $dh = \alpha\,\theta\,v\,ds$ where α is a constant depending on the shape and arrangement of the parts.

$\therefore h = \alpha\,\theta \int v\,ds$ when θ is uniform.

When the armature section is a rectangle of breadth b and radii R & r, running at n revs: per sec:

$$\int v\,ds = 4\pi^2 bn\,(R^2+r^2) + 2\pi\,(R^2-r^2)\,2\pi n\left(\frac{R+r}{2}\right)$$

$$= 4\pi^2 n\left\{b\,(R^2+r^2) + (R^2-r^2)\,\pi\left(\frac{R+r}{2}\right)\right\}$$

$$\therefore h = F + c^2\rho = 4\alpha\,\theta\,\pi^2 n\left\{b\,(R^2+r^2) + \frac{\pi}{2}(R+r)\,(R^2-r^2)\right\} \qquad (1)$$

If now $(R-r) = b$

we have $F + c^2\rho = 4\alpha\,\theta\,\pi^2 n\left[b\left\{(r+b)^2+r^2\right\} + \frac{2r+b}{2}\cdot b\,(2r+b)\right]$

$$= 4\alpha\,\theta\,\pi^2 nb\left\{(r+b)^2+r^2\right\} + \left(\frac{2r+b}{2}\right)^2\Big]$$

nearly $= 4\alpha\,\theta\,\pi^2 nb\,(2r+b)^2 = 4\alpha\,\theta\,\pi^2 nb\,(2R-b)^2$

so that for two different sized machines having a common value of θ

$$\frac{F_1 + c_1^2\rho_1}{F_2 + c_2^2\rho_2} = \frac{n_1 b_1\,(2r_1+b_1)^2}{n_2 b_2\,(2r_2+b_2)^2} = \frac{n_1 b_1\,(2R_1-b_1)^2}{n_2 b_2\,(2R_2-b_2)^2}$$

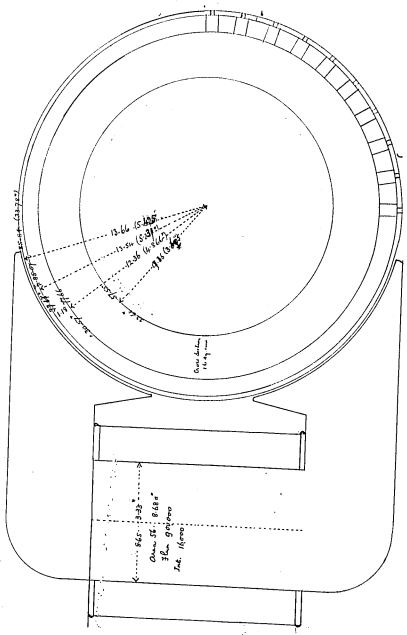
$$= \frac{n_1 b_1\,R_1^2}{n_2 b_2\,R_2^2} \text{ about.}$$

Since the peripheral speeds of a series of machines should be constant this reduces finally to

$$\frac{h_1}{h_2} = \frac{F_1 + c_1^2\rho_1}{F_2 + c_2^2\rho_2} = \frac{b_1 R_1}{b_2 R_2}$$

Edison quadripolar 2 kw. motor section through armature and one magnet.

½



Calculations for a 2½ H.P. (2000-Watt) Edison motor to run at 1400 r.p.m. on 120 volts terminal p.d.

Referring to the formula on page 120

$V = 2000 \quad \therefore \frac{V}{2n} = 318.3$

$n = 1400/60 = 23.33 \quad \therefore \pi R = 13.66.$

With a drop of 0.05 in the armature at full load = 6 volts and a commercial efficiency of 0.7, the intake will be $2000/0.7 = 2860 \div 120 = 23.83$) and $6/23.83 = 0.25$ of which 0.8 or 0.2 (hot) may be in the armature proper. The ohmic loss of energy at full load will be $(23.83)^2 \times 0.2 = 113.6$ Allowing 160 watts lost in Foucaults, and the total H = 275

In the 1 H.P. motor H = 200 and $\pi b = 38.5$

$\therefore b_2 = \frac{275}{200} \times \frac{38.5}{13.66} = 3.876$. Say 4 = b = K.

With $\sigma = 14{,}000 \quad \phi = 2 \times 16 \times 14{,}000 = 2 \times 1.6 \times 1.4 \times 10^5 = 448{,}000$

$\phi n = 2.333 \times 4.48 \times 10^6 = 1.0452 \times 10^7$

$w = 1.2 \times 10^{10} / 1.0452 \times 10^7 = 1148 \div 36 = 31$ nearest $+36 \times 32 = 1156$

32 = 6 layers of 5 + 2 on top.

The mean turn will be $4 \times 5 + 2 = 22$ cm

The total length of wire will be $22 \times 1156 / 30.48' = 805.5'$

The equivalent length . . . $805.5/16 = 50.35$ for 0.2 ω (hot)

Wire has 251.75 feet per ohm @ 100°C = #17 B.W.G. 0.058" cond. & 0.071" and the width of groove = $5 \times 0.071 = 0.355 + 0.03 = 0.385$

The depth of groove = $6 \times 0.071 = 0.426" + 0.04 = 0.456" = 1.18$

The total segment of the outer groove circle occupied by groove is $36 \times 0.385 = 13.86$

. . . . . teeth is $19.92 = \frac{0.456}{0.426}$

. . . . . iron . . . . . is $16.71 = \frac{0.456}{0.426}$

Arc of polar gap. 30: of polar face 60°.

Segment of polar face $14.31 \times 4 = 57.25$ sq. cms.

Number of teeth carrying flux 6 each $4 \times 1.285 = 30.8$ sq. cms

Density of flux in teeth = $448{,}000 / 30.8 = 14{,}540$.

As this is rather too great an interval it will be advisable to increase the breadth to 5, and the depth to 3.2

The Polar surface will now be $14.31 \times 5 = 71.55$ sq. cms.

Density in teeth $448{,}000 / 38.55 = 12{,}620$

. . . air $448{,}000 / 71.55 = 6{,}260$.

Reluctance of air circuit $2 \times 0.1 / 35 = 0.00570$

Surface of armature $\pi(13.66^2 - 9.16^2) = \pi(186.6 - 83.9) = \pi(82.7) = 259.8$

$259.8 - (36 \times 1.18 \times 0.85) = 259.8 - 36.1 = 223.7$ sq. cms $\times 5 = 1119$ c.c.

and $1119 \times 7.8 \times 9 = 78000$ gms. = 19.9 lbs.

The cross section of the field core must be $\frac{2 \cdot 0 \times 448{,}000}{16{,}000} = 56.0$ sq. cms.

= 0.85 cms. diam. = 3.327" diam.

Reluctance in iron of circuit 64 cms. of 16 sq. cm. at 15,000 = 4 cms @ 0.005 = 0.025. The MMF required to drive 225,000 lines through this will be 3,500 = 3600 A.T. at ½ flux the MMF will be 900 A.T.

Estimated weight of this motor 340 lbs. complete.

Experiment to determine the amount of Local action in some Edison-Lalande cells left on open circuit 30th Apr. 91.

Four new "C" cells were made up with solution of NaHO in hot engine room water, sood of sp. g. 1.27, and marked nos. 1, 2, 3 & 4. Nos. 1 + 2 had plain, unamalgamated zinc, nos. 3 + 4 amalgamated zinc. They were weighed in (a) (19)+ grains on the store room scale. These weights are given in grammes.

Date of Cell	Weights 30.IV.91	11.V.91	12.V.91	16.V.91							
1	102.95	97.03	68.2	52.							
2	99.69	94.77	69.0	66.							
3	113.89	110.0	113.7	112.5							
4	110.64	110.0	112.7	111.5							

Data concerning 100-Kwt. dynamos tested at Schenectady 1st May 1891.

The engine made 187 r.p.m. at no load and 165 r.p.m. at full load. The dynamos delivered steadily 500 amp. each at 128 volts. = 640 KW. The full load by design being 666 amp. at 130 volts. About 36 amp. in field. Some sparking at brushes

Table

Conclusions arrived at Concerning the rerating of standard motors for the E. G. E. Co, after an interview with Messrs Kunz & Hellen 1st May 1891.

That the output of all standard Edison generators for 125 and 250 volts except # 6, 8, 10 + 12, and all generators for 500 volts except 28 & 10 + 12 inclusive should be advanced in rating up to heat limit of their output.

That this same increase should be given in each case to corresponding machine when detached as a motor.

That the power of each motor should be determined by multiplying its rated number of watts into its commercial efficiency determined by actual test.

That the fact of the designed motor pressure being 250 volts, whereas at the present time only 220 volts is generally attainable, should not cause any change in the rating, but that any complaints made on the score of insufficient pressure should be dealt with individually.

The following are therefore the new ratings compared with the existing one.

Number	Volts	Ampères output	Watts	New rating Ampères	New rating Watts	Commercial eff.	Motor Power Watts	Brake HP to pressure of 220 volts	Brake HP of old motor	Brake HP of new rating at 110 volts	Brake HP of 500 volt rating at 110 volts
								(Foot lbs)			Rule 18
50 Wt	110	2.3	253	4.545	500	0.7	350	0.469	0.25	0.47	177.1
	110	4.5	495	6.818	750	0.73	547.7	0.734	0.5	0.73	361.3
	110	9.	990	13.64	1500	0.76	1140.0	1.528	1.0	1.5	752.0
	125 / 250 / 500	20 / 10 / 5	2,500	24.00	3000	0.78	2340.0	3.137	2.5	2.76	1900 2.61
	125 / 250 / 500	40 / 20 / 10	5000	48.0	6000	0.80	4800	6.432	5	5.66	4000 5.26
	125 / 250 / 500	60 / 30 / 15	7,500	68.0	8500	0.825	7014	9.402	7.5	8.27	6190 8.30
	125 / 250 / 500	80 / 40 / 20	10,000	96.0	12,000	0.85	10,200	13.670	10	12.03	8500 11.39
	125 / 250 / 500	120 / 60 / 30	15,000	120.0	15000	0.865	12,980	17.40	15	15.31	12,900 17.4
	125 / 250 / 500	160 / 80 / 40	20,000	160.0	20,000	0.885	17,700	23.73	20	20.57	17,700 23.7
	125 / 250 / 500	200 / 100 / 50	25,000	200.	25,000	0.890	22,250	29.83	25	26.25	22,250 29.8
	125 / 250 / 500	240 / 120 / 60	30,000	240	30,000	0.890	26,700	35.79	30	31.49	26,700 35.8
	125 / 250 / 500	320 / 160 / 80	40,000	380.0	45,000	0.895	44,300	59.39	40	52.28	44,300 59.4
	125 / 250 / 500	400 / 200 / 100	50,000	480.0	60,000	0.9	54,000	72.38	50	63.70	54,000 72.4
	110 / 220 / 500	275 / 137.5 / 55	30,500	714.3	100,000	0.92	92,000	123.30	80	108.5	92,000 123.3
	110 / 220 / 500	1075 / 660 / 300	150,500	1250.0	175,000	0.92	161,000	215.8	150	189.9	161,000 215.8

To Transform the expression $\left(\frac{d^2v}{dx^2} + \frac{d^2v}{dy^2} + \frac{d^2v}{dz^2}\right)$ into polar coordinates, having given

Lightning arrestors for Edison Illuminating Stations.

150 of these finished arrestors, completing the order for 200 see p. 129. These were received on the 3rd May. They were all tested at the full pressure of the municipal machine the same day – about 1250 volts. 6 of them were lost in testing, (principally owing to faults in the edges of the condensers. This left 144 available. The following disposition was made of these arrestors.

1	Edison Illuminating Co	Boston	Mass.	11
2	" " "	Chester	Pa	11
3	" " "	Scarborough	Me	6
4	" " "	Birmingham	Ala	11
5	" " "	Topeka	Kans	11
6	" " "	Elgin	Ill.	11
7	" " "	Kansas City	Mo.	9
8	" " "	Rochester	N.Y.	11
9	" " "	Lawrence	Mass.	11
10	" " "	Appleton	Wis.	11
11	" " "	Des Moines	Iowa	11
12	" " "	Detroit	Mich.	6
13	" " "	Philadelphia	Pa.	6
14	" " "	Harrisburg	Pa.	6
15	" " "	Engineer-in-Chief	N.Y.	6
16	" " "	returned		6
				Total 144.

A (capacity) test was made on twelve as follows:–

No.	Capacity	Mean	v	v^2	$0.6745\frac{\Sigma v^2}{\sqrt{n-1}}$	$0.8453\frac{\Sigma v}{\sqrt{n(n-1)}}$	probable error for single condenser	
1	0.016 f		-2×10^{-3}	4×10^{-6}	$0.2029\times4.42\times10^{-3}$	$0.0736\times12\times10^{-3}$		
2	0.016 f		-2×10^{-3}	4				
3	0.013 f		1×10^{-3}	1	$+0.907\times10^{-3}$	0.8832×10^{-3}		
4	0.014 f		0					
5	0.015 f		-1×10^{-3}	1				
6	0.012 f	0.0141 f	2×10^{-3}	4			0.0009 f or 6.4%	
7	0.015 f		-1×10^{-3}	1				
8	0.013 f		$+1\times10^{-3}$	1				
9	0.012 f		2×10^{-3}	4				
10	0.014 f		0					
11	0.012 f		0					
12	0.012 f		0	20×10^{-6}				

A distinct shock could be felt from these condensers after having been charged for an hour from after contact with 1250 volts

Weight of field wire per foot 0·098 lb. × 518 = 50·8 lbs. say 50·5
- - - - on all four cores = 290 lbs.
Diameter covered = 0·192" = 52 turns per layer = 6 layers.
Total copper on field 261 lbs.
Drop in field at full load 28·8 volts.
- - machine - - - 88·8 -

[illegible] OF EDISON [illegible] GRADE HOOK WITH CAST STEEL FIELD, [illegible] MAX.
[illegible] original data for construction of 1st. motor [illegible]
[illegible] Quadripolar armature-ring series wound.
[illegible]. To pull a street-car weighing loaded 20,000 lbs. [illegible] up
[illegible] grade at the rate of [illegible] miles an hour [illegible] speed and
[illegible] velocity ratio of the motor and car wheel axles being
[illegible] and the car-wheel having a diameter of 30".
Torque needed at full load 338 ft-lbs. at armature shaft.
[illegible]ower needed in driving car at full load 12 EM. [illegible] H.P.
[illegible]owing [illegible] efficiency [illegible] 10%, or 21 HP. [illegible]
[illegible] from at terminals 300, amperes at full load [illegible]
[illegible] of armature 250 to 300 r.p.m.
[illegible]ximal velocity 1200 to 1500 f.p.m.
[illegible] dimensions, Diameter over all 25.41"
over conductors 25.[illegible]"
over body insulation 25.0"
over body 23.5"
inner body 21.25"
Polar bore 20.10" max. 20"
Clearance 0.31"
Breadth of armature above 5 1/2"
below 5 1/2"
mean [illegible]"
[illegible]ross section of armature core [illegible] sq. in.
Estimated weight of iron in armature 350 lbs.
Armature wire # 1 [illegible] 0.065" s.c.c. to 0.071"
[illegible] 850 turns in three layers.
[illegible] over blocks 250 [illegible] winding continuous armature-ring every
twelfth coil height [illegible] to commutator, sections
four inches wide and three high.
[illegible] length of wire on armature [illegible] weighs 61 lbs.
[illegible] of wire [illegible] each side, or [illegible] c.m. per ampere at load,
[illegible] of armature including [illegible] connections [illegible] ohm (hot)
[illegible] of armature at full load [illegible] Volts.
[illegible] in armature [illegible]
~~[illegible] are four diameters [illegible]~~
[illegible] in branches four in number and each double.
[illegible] in series connections (of same [illegible] as that now used
[illegible] or present core [illegible] [illegible] 1/8 [illegible] P.W.G. [illegible] standard)
[illegible] and keepers of good magnetic cast steel [illegible] [illegible] diameter
[illegible] long 11", interflange 10.5" Shoat [illegible] 1/2"
or [illegible] 13.25 lbs. on each core 61 lbs. in all.
[illegible] in series field. All four cores in series, but divided
[illegible] each core into three equal parts for compensation.
each core into three equal parts for compensation.
[illegible] lbs. of # 7 P.W.G. 0.180" s.c.c. to 0.19" sq. on each
spool; each division [illegible] 1/4 lbs. 1 making 500 lbs. [illegible]
[illegible] four cores [illegible] in all 0.[illegible] ohm (hot.)
[illegible] of [illegible] spools [illegible] in all [illegible]
[illegible] of wire on each spool about 210'.
Total length of wire on [illegible] 1000 [illegible].
[illegible] in field at full load 1000 watts.
Total weight of copper in field including shoat 2[illegible] lbs.
[illegible] in field at full load [illegible] volts. [illegible] in machine [illegible] volts
[illegible] in field at full load [illegible] volts. [illegible] in machine [illegible] volts

Modifications in the Edison 6% grade motor to suit Series winding and cast steel field magnets.

The original design see page 100.
Now specification is as follows:—
A bipolar motor series wound to haul a car weighing 20,000 lbs, on a 6% grade at the rate of four miles hour with resistance in circuit. Normal speed at full saturation to be 6 mph. with wheels. 500 volts.

Full load = 1200 + 10×15 = 1350 lbs. at car axle = 16.98 ft-lbs = 337.6 ft-lbs. at armature shaft = 153.1 kgm. ft = 11.668 × 10^6 cm-gms. = 11.58×10^2 dyn cm
Speed = 6 mph. = 67.2 r.p.m. of car wheel
Gearing ratio 5 : 1 = 336 r.p.m. of motor say 360 = 6 tr sec.
Same flux as in previous design 2.4 ×10^6 from each pole
Turns = $\frac{5}{144}$ × 10^3 = 3473 wires say 3360
Commutator blocks, and armature sections 280, 12 wires per section.
Gramme-ring armature continuous winding.
Diameter of armature body over insulation 28.0" Core: 8 8"
Allowing d.g. factor of winding = 79.2" ÷ 1120 = 0.0707" and allowing 0.0127" for d.c.c. = 0.058" bare copper wire = #17 B&S Ga 3364 c.m.
Height of winding 3 × 0.071 = 0.213", diameter over wire 28.426"
Diameter over binding wire 28.606" 0.0g" for binding
Tolerances 1/16". Polar bore 28.981".

Resume of dimensions.

		mins.	mm	cm.
Body int. diameter	21.15"	66.44	53.72	168.7
ext. "	27.90"	87.65	70.86	222.7
over insulation	28.00"	87.96	71.12	223.4
" conductors	28.426"	89.3	72.2	226.8
" binding	28.606"	89.86	72.66	228.3
of polar bore	28.981"	91.04	73.60	231.2

Entrefer 0.54", 1.37 mm.
Mean turn = 1.92' and 3360 turns = 6452' ÷ 16 = 403' equivalent
R = 4.03 × 3.952 × 10^{-1} = 1.6 ω hot (100°C) allowing for 3.2 say 1.75 ω
6452 × 0.0102 = 65.8 lbs. of wire.
Drop in armature at full load 1.75 × 34.3 = 60.0 volts.
Energy " " " " 34.3 × 34.3 × 1.75 = 2058 watts.
Torque at full load assuming full flux thro armature
3.43 × 3.36 ×10^3 × 2.4 × 10^6/6.283 = 14403 ×10^3 cm. dyn = 14.49 ×10^6 cm gm
= 1.473 ×10^5 ft. gm = 3.247 ×10^2 ft. lbs. at armature shaft = 16.235×10^2 ft lbs. at car axle = 1280 lbs. at axle.
Cores and Keepers of cast steel. Density 14,000 1 - 1.5 3.6×10^4 lines
in each core $\frac{3.6}{1.4}$ ×10^4 = 2.57 ×10^4 = 257 sq.cms = 18.1 equal diam.
= 7.13" diam. = 39.6 sq.in. Length 11" = 27.94 Entireflange 10.5" = 26.67
Thickness of copper 7/16" = 0.476. Diameter over copper 7.505" 19.05
Volume of copper sheet on each core 3.14 × 0.476 × 27.94 × 18.6 = 777 c.c.
777 × 8.9 = 6196 gms = 15.25 lbs. and on all four cores 61 lbs.
Spool diameter internal 7.7"

Magnetic circuit

		length	cross section	4/π	Σ	ρ	R
	Armature	40	1240	0.32	8000	0.001	0.0032
½ Cores		150	128'	1.2	14000	0.0015	0.0018
	Entrefer	2.74	1440	0.00127	"	"	0.00237
						Total	0.10858

To force 1.2 ×10^6 lines through a reluctance of 5.35 10^{-3} needs 19,920 mmf = 20,000/2 amp turns. on each spool = 223 turns of 24 amperes allowing double
With 1000 Watts expended in the field at full load we have
$\frac{1000}{(37.3)^2}$ = 0.84 ω as field res: hot = 0.21 ω per spool, and the mean turn = 8.4"×3.14/12 = 2.2' = 593' for 0.21 ω = 2.64' per ω = #7 B&S 0.1875

DATA OF EDISON UK GRADE STREET-CAR MOTOR WITH CAST STEEL FIELD
Of original design and construction of 2nd. Market 1891.

The quadripolar gramme ring series wound.
Work to pull a street-car weighing 20,000 lbs. up a 4% grade
at the rate of four miles an hour without overload.
Torque needed at full load 380 ft-lbs. at armature shaft.
Power needed in driving car at full load 12 KW. or 16 HP.
Allowing 70% efficiency 17KW. or 23 HP. absorbed.
Voltage at terminals 500, Amperes at full load 34.4
Speed of armature 250 to 700 rpm. Peripheral velocity 1900 to
5320 f.p.m. Velocity ratio of car and motor axles 5.
Diameter of car wheel 40".
Machine dimensions:-Diameter over all 22.62"
over connectors 22.62"
over insulation 22.07"
over body 20.79"
inside body 18.07"
Polar body [illegible]
Length air 1/4
below 1/4"
[illegible] 7"
Cross section of armature core 28.62 sq. in.
Estimated weight of iron in armature 270 lbs.
Armature wire # 12 B&S, 0.0 d" d.c.c. to 0.07" [illegible] with
0.8 mils. or 20 c.mils. per ampere at full load.
Resistance of armature not including German silver wires [illegible]
drop in armature at full load 38 volts. Energy 1521 watts.
Commutator blocks 260 Winding consists of one gramme ring wound
[illegible] half turn brought to commutator. Sections three wires
[illegible] and four high. 3360 wires in all in 6 layers
[illegible] on armature 1320 Weight 8.5 lbs.
[illegible] wire and each double
[illegible] and as [illegible]
[illegible] 168 wires around
[illegible] in each stool [illegible] in [illegible]
[illegible] 11". [illegible] Shunt copper 2/10 or 15.2
[illegible] 61 lbs. [illegible]
[illegible] coils in series for each coil
[illegible] for commutation.
[illegible] to 0.15" on each core
[illegible] lbs. of [illegible] 0.100" [illegible] to 0.15" on each core
[illegible] 1 [illegible] lbs. making 200 lbs. in all. About
[illegible] of 2 wires each. Length of winding [illegible] turns, of
[illegible] 0.91 dia. in all 0.91 dia. (hot).
[illegible] about 210'
Total length of wire on each spool about 210'
[illegible] in field at full load 1000 watts.
[illegible] weight of copper on field including shoes 241 lbs.
[illegible] at full load [illegible] volts. In [illegible]

Fresh modifications in the 6½ grade motor to suit an armature, the polar bore of which is 24" in diameter.

			Circ.	Diam.	Circ.
Diameter of polar bore	24"	.	75.4"	60.96	191.5
Clearance ¾" 0.1875"					
Diameter over binding	23.625".		74.22"	60.01	188.5
Binding thickness 0.080"					
Diameter over conductor	23.485".		73.78"	59.66	187.4
Conductor 4 wire 0.077"-.0398	22.869".		~~71.90~~	58.09	182.5
Insulation ~~0.05~~ 0.014"					
Diameter over body	22.789".		71.60"	57.88	181.8
Depth of body 3.375					
Diameter under body	16.039".		50.4"	40.74	128.0

26214 / 1301 / 1323

Allowing winding factor of 0.9 upon the insulation circumference 64.71" which divided by 840 gives 0.077", and allowing 0.013" for insulation yields 0.064" for the wire = #14 B&S 4109 c.mils. or 119.8 × 4 = 480 c.mils. per ampere. at 34.37 full load 290 Commutator blocks, 3360 wire in 4 layers of 840, winding 4 high 3 wide.

Magnetic circuit.

	L	B.	S/A	L	ρ	R.
Entrefer 1.54 cm	1.54	640/2	0.0448	-	-	0.0448 / 0.0448
Cores and poles	150	12.8	1.2	14,000	0.0015	0.0018
Armature	40	126	6.32	8,000	0.003	0.001
						0.0124

To force 1.2×10^4 through 1.24×10^{-3} needs MMF = 14.88×10^4 = 11840 A.T. = 5920 A.T on each spool. Provision is made for 8000 A.T at full load.

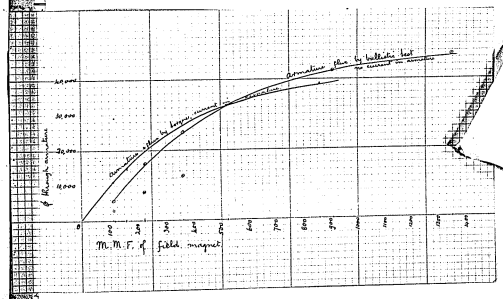
The equivalent length being $\frac{2 \times 3360}{16}$ = 420' and res per foot 3.238 × 10⁻³ = 0.136 = hot and 9.5. wire may increase this to ≈ .16.

The weight of wire = 2.0 × 3360 × 0.01245 = 83.6 lbs.

The drop at full load is ≈ .16 × 34.3 = 54.9 ≈ energy 1883 watts.

The area of armature annulus is 1323 sq. cm. × 17.8 × 5.3 = 12448 kgms. = 275 lbs.

$$\phi = \frac{2\pi}{CW} \quad \frac{6.283}{12K} \times \frac{1}{C} = \frac{0.14188 \cdot T}{C}$$



Test of Lee-Fuller cells. commenced 7th May 91.

Two of these cells were set up on the 7th May according to maker's directions as follows:—

Solution in outer cell 298 c.c. of H_2SO_4 sp. g. 1.65 - 492 gms.
Na_2CO_3 170 gms
H_2O 1600 gms.

- inner porous cell with zinc plunge bot $NaCl$ 80 .
H_2O 400 .

Weight of zinc #2 512 gms (1 lb. 900 gms) Zinc #1 538.1 gms (1 lb. 1150 gms)

E.M.F. of cell no 1. 2.068 volts P.D. in 2 w 1.82 volts
- - 2 2.060 - - - 1.80 -

May 25th Weight of zinc	#1 420 gms.	#2 443 gms
June 12 "	360.5 .	385.5 .
July 16th	312 .	340 .

Test of Arc lamp motor 7th May 91.

1st Test sent a steady current of 8.33 ampères through the armature and a variable current through the coarse winding of the field. By means of a scalepan and weights suspended by a string over the commutator, measured the torque produced as follows:—

	Volts	Amperes in field cct	Amp. Turns	MMF field cct	Red. of string	Weight of pan	Weight added	Total weight	Moment compen	Moment dyne cms	Equivalent of calibrated spring	Torque in ergs	
1	0	0	0	0	2.4	24	20	44	105	1.03×10^6	5180	2.590	
2	0.230	1.199	91.12	114.5			70	94	225.6	2.213 .	11,130	5.565	
3	0.325	1.694	128.7	161.7			100	124	297.6	2.92 .	14,690	7,345	
4	0.451	2.353	178.8	224.8			150	174	417.6	4.097 .	20,610	10,305	
5	0.645	3.448	261.0	328.4			250	274	657.6	6.452 .	32,460	16,230	
6	1.735	9.046	687.5	864.2			300	324	777.6	7.628 .	38,380	19,190 .	
7	0	0	0	0			90	114	273.6	2.685 .	13,510	6,755	

2nd Constant field varying armature

	Current in field amp.	Volts across	Amp Turns	MMF field cct	Current in Shunt	in field amp.	Weight added	Total weight	Moment compen	Moment dyne cms	Equivalent of calibrated	Moment per amp	
1	0.062	0.2608	35.03	42.03	2×0.362	3.505	0	24	57.6	5.65×10^5	2,820	1.24×10^5	
2	0.122	0.9247	70.27	88.3			20	44	105.6	1.036×10^6	46,900	1.121 .	
3	0.163	1.395	106.0	133.2			40	64	153.6	1.507 .	45,220	1.081 .	
4	0.2286	3.226	245.2	308.2			100	124	297.6	2.92 .	37,900	0.905 .	
5	0.5774	4.348	330.3	415.2			120	154	369.6	3.626 .	34,930	0.834 .	
6	0.963	6.90	524.4	659.2			180	204	489.6	4.991 .	30,300	0.723 .	
7	1.0724	8.074	613.6	771.3			200	224	537.6	5.274 .	27,360	0.653 .	
8	0.360 (Shunt)	1.577	142.16	179.2	Resp 0.1638	1.233	0	24	57.6	5.65×10^5	12,600	5.01×10^5	
9	0.724	3.775	286.9	360.6		1.2071 (resistance)	20	44	105.6	1.036×10^6	11,500	2.745 .	
10	1.144	5.965	453.6	570.2		1.2071	50	74	177.6	$1.742 \times$	12,230	2.920 .	
11	1.522	7.936	602.2	758.2		94.3 ohms 119.2 mm	70	94	225.6	2.213 .	11,650	2.788 .	
12	1.860	9.698	1276.	1604			90	114	273.6	2.684 .	11,600	2.769 .	
13	2.220	11.575	1523.	1914	0.1673	1.260	100	124	297.6	2.920 .	10,570	2.523 .	

Theory of the lamp

Let ϕ be the circuital flux passing through the armature c.c.s.
I . . current in the main circuit abs.
v . . pressure on the lamp terminals abs.
n . . turns on the series winding
N . . . . . shunt
r . . res: of . . . . .
ρ . . Effective reluctance of the magnetic circuit.
w . . mass carried round the armature
~~Then~~ g . . gravitation force on the upper carbon dynes
m . . . . mass of . . . . gms.
f . . frictional force . . . . = ~~spring gms~~
r . . radius of pitch circle of the lifting pinion cms
l . . length of the arc cms

Then when the current is started through the lamp we must have $\frac{\rho w r}{2\pi} > mgr(1+\mu)$

$$\text{or} \quad \frac{4\pi I n w}{2\pi\rho} > mgr(1+\mu)$$

This being the case the carbons will separate.
Leaving out of consideration the kinematical analysis of the motion, assume that the arc becomes steady at a length l such that :—

$$\frac{\rho w r}{2\pi} = mgr$$

where $\frac{4\pi I n - 4\pi \frac{v}{r} N}{\rho} = \phi$

$$\frac{4\pi}{\rho}\left(In - \frac{v}{r}N\right) = \phi = \frac{2\pi mgr}{wr}$$

$$\text{say} \quad In - \frac{v}{r}N = \frac{mgr\rho}{2wr}$$

$$\text{let } v = \alpha + \beta l$$

$$In - \frac{N}{r}(\alpha + \beta l) = \frac{mgr\rho}{2wr}$$

The ~~variation~~ torque for a change of Δl is

$$\frac{2}{\rho}\left\{In - \frac{N}{r}(\alpha + \beta l)\right\} wr = T$$

$$\frac{dT}{dl} = \frac{2}{\rho}\left(-\frac{N}{r}\beta\right) wr = -\frac{2wr}{\rho}\frac{N\beta}{r}$$

which for proper regulation should be as large as possible. That is to say its MMF should be as great as possible, and consequently the opposing MMF should be as great as possible. There should thus be as many turns as possible on the series coil, with very powerful damping to resist the ~~variation of motion~~ acceleration.

Test of Ato = lamp continued.

Magnetic circuit test as follows:—

Ref No.	Source of EMF	E.M.F	Lapping	Throw	a	q - per div
1	1 B.C. 17°C	1·4358	1p	103	1.4358×10^{-7}	1.394×10^{-9}

Ref No.	Current thru' mec: field Ohmch	amp	Amp turns	MMF	Throw	a	Res of G	ϕ	$\frac{\phi}{\rho}$ (c.c.)	Total mm flux 2ϕ		
1	0·24	1·251	9508	119·5	4	5.576×10^{-7}	5.25×10^{-4}	2.927×10^{3}	1,950	3,850		
2	0·452	2·307	17,49.1	225·1	11	1.338×10^{-6}		8.05×10^{3}	5,350	16,100		
3	0·73	3.806	28,9.5	363.9	17	2·37		1.244×10^{4}	8,290	24,880		
4	1·82	9.149	72,1.2	906.4	29	4·043		2·123	$14,150^{\circ}$	42,460		
5	2·70	14·05	107,0.	1345	32	4·461		2·342	$15,660^{\circ}$	46,840		
6	5·20	27·10	205,9	2588	32·5	4·531		2·379	$15,860^{\circ}$	47,580		

Data for a new arc lamp design.

The weight of the rod is 800 gms and the carbon of present length 50 gms. With increased length of carbon, and the load on the rod necessary to ensure the weight of carbon being relatively small, the total weight to be lifted will be 750 gms. The pitch radius of the rack is about 1·27 cms, so that the gravitational moment is 950 cm-gms, with no friction.

With 1·75 sq. cms. of armature cross-section and a density of 14,000 giving a useful flux of $3.5 \times 14{,}000 = 49{,}000$ say 50,000 lines. $= \phi$
9 amperes and 150 turns on the armature give a moment of

$$\frac{5.0 \times 10^{10} \times 0.9 \times 1.5 \times 10^{-2}}{6.165 \times 10^{3}} = 1095 \text{ cm-gms say } 1100.$$

The armature surface is opposite to each pole 22·5 sq. cms, with an entrefer of 0·1 so that the reluctance in the air gap is $\frac{0.2}{22.5} = \frac{1}{112.5} = 0.00886$, and in the whole circuit 0·01 at low saturation so that 4 force 50,000 lines through this needs 500 mm $= 4.00$ AT. $= 44$ turns. Allow 100.

At low saturation the variation in torque would be proportional to the current, so that the a change of one amp: in the main cct: would vary the torque about 120 cm-gms.

The cross section of the magnets had to be 3.5 sq. cms for useful lines & 0.07 for leakage

Check 1" has a diam. of 2.54 cms and an area of 5.067
its surface per cm. is $3.14159 \times 2.54 = 7.98$ cms, and it can therefore
deliver $\frac{7.98}{20} = 0.399$ watt.
Its res. per cm. is $\frac{2.0 \times 10^{11}}{5.067} = 0.395 \times 10^{11}$ abs. units $= 3.95 \times 10^{3}$
and the heat from 318 amps will be $101100 \times 3.95 \times 10^{-6} = 1.01 \times 3.95 \times$

067
therefore
$1.5 \times$
7.5×10^3
01×3.95 km.

BLE OF THE RESISTANCE AND CARRYING CAPACITY OF GALVANISED
RON WIRE ENCLOSED IN VENTILATED CHAMBERS. 8th. MAY 1891

Wire Gauge	Diam. Inches	Resistance.	R per ft. (Ohms)	Amperes.
5	0.1819	34086	0.00845	24.7
6	0.1642	26244	0.00435	20.8
7	0.1443	20832	0.00529	17.5
8	0.1285	16512	0.00892	14.8
9	0.1144	13067	0.00673	12.8
10	0.1019	10364	0.0110	10.3
11	0.091	8226	0.0139	8.7
12	0.0808	6529	0.0175	7.3
13	0.072	5184	0.0221	6.2
14	0.0641	4109	0.0278	5.2
15	0.0571	3260	0.0351	4.3
16	0.0508	2581	0.0442	3.7
17	0.0453	2052	0.0558	3.1
18	0.0403	1624	0.0704	2.6
19	0.0359	1289	0.0887	2.2
20	0.032	1024	0.112	1.8
21	0.0285	812	0.141	1.5
22	0.0253	640	0.178	1.3
23	0.0226	511	0.225	1.1
24	0.0201	404	0.283	0.9
25	0.0179	320	0.357	0.70
26	0.0159	253	0.450	0.64
27	0.0142	200	0.569	0.56
28	0.0126	159	0.716	0.48
29	0.0113	128	1.02	0.34

e resistances in column 4 are the resistances per foot of
e wire at 100° Centigrade. This can only be regarded as
approximate since different samples of iron wire vary both
e resistivity and temperature coefficient.
e currents in the last column are the limiting currents
the currents in the last column are the limiting currents
hat each wire can safely carry when enclosed in a well
entilated box, and are such as will bring the temperature
the wire from 20° to 100° degrees Centigrade under the same limit
nditions. When the ventilation is imperfect, the same limit
temperature may be reached with perhaps only one third
the current strength tabulated.

Data for the heating of iron wire in resistance boxes

will probably be safe to allow 266 cal: cms: per watt, and a resistivity of 8.5×10^{-6} at 100° c.

Calling ρ the resistivity at 100° c
r . rad: of the wire
e . emissivity per cal: cms: of surface ~~abs~~ cal per sec:
c . current in abs: measure

$$\frac{c^2 \rho}{\pi r^4} = 2ne r$$

$$\therefore c^2 = \frac{2\pi^2 e r^3}{\rho}$$

$$c = \pi\sqrt{\frac{2e}{\rho}}\, r^{\frac{3}{2}} \quad \text{with } r \text{ in cms}$$

$$\gamma = 10\pi\sqrt{\frac{2e}{\rho}}\, r^{\frac{3}{2}} \quad \ldots \quad \gamma = \text{amperes.}$$

$$\gamma = 10\pi\sqrt{\frac{2e}{\rho}}\, \frac{r^{\frac{3}{2}}}{(2.54)^{\frac{3}{2}}}(2.54)^{\frac{3}{2}} \quad \ldots \quad \text{inches.}$$

$$= 31.416 \times \sqrt{\frac{2 \times 266 \times 10^6}{8.5 \times 10^{-6}}} \times (2.54)^{\frac{3}{2}} \times r^{\frac{3}{2}} \times 10$$

$$= 3.1416 \times \sqrt{50} \times 4.05 \times 10\, r^{\frac{3}{2}}$$

$$= 3.1416 \times 7.07 \times 4.05 \times 10 \times \frac{d^{\frac{3}{2}}}{2.828} \quad \text{where } d \text{ is in inches}$$

$$= 318.2\, d^{\frac{3}{2}}$$

Diam:	$D^{\frac{3}{2}}$	γ	Res: Rot: per foot	No. B.W.G.	Diam	$D^{\frac{3}{2}}$	γ	Res: Rot: per foot.
0.819	0.07752	24.66	3.453×10^{-3}	19	0.03589	0.006805	2.165	0.08873
0.642	0.05245	20.82	4.354	20	0.03196	0.005716	1.819	0.1119
0.643	0.05487	17.46	0.00549	21	0.02846	0.004801	1.528	0.1411
0.285	0.0146	11.64	0.006972	22	0.02535	0.004035	1.284	0.1781
0.244	0.0386	12.28	0.008730	23	0.02257	0.003389	1.079	0.2246
0.019	0.0325	10.34	0.01401	24	0.0201	0.0028851	0.907	0.2828
0.707	0.02733	8.695	0.01386	25	0.0179	0.002395	0.762	0.3572
0.708	0.02297	7.309	0.01750	26	0.01594	0.00201	0.6396	0.450
0.720	0.01934	6.154	0.02206	27	0.014195	0.001689	0.537	0.5686
0.641	0.01623	5.164	0.02783	28	0.01264	0.001423	0.453	0.6258
0.571	0.01365	4.343	0.03509	29	0.01126	0.001194	0.380	1.015
0.508	0.01145	3.643	0.04424	30	0.01003	0.001005	0.320	1.137
0.453	0.00965	3.071	0.05580	31	0.00892	0.000844	0.267	1.434
0.403	0.008096	2.577	0.07038	32	0.00795	0.000707	0.226	1.814

The res: per cm: $= \dfrac{\rho}{\pi r^4}$ where r is in cms

$\dfrac{\rho}{\pi r^4 (2.54)^4}$ . . . . inches

or

$\dfrac{\rho}{\frac{64}{4}\pi d^4}$ - d . . . inches.

$\dfrac{\rho}{1.642\,\pi d^4}$ - . . . .

$\dfrac{8.5 \times 10^{-6}}{5.222\, d^4}$

$\dfrac{4.577}{5.222} \times \dfrac{10^{-6}}{d^4} = 0.875 \times 10^{-6} \left(\frac{1}{d^4}\right)$ ohms per foot: rot.

Test of a small two bladed fan motor from Silvertlake 8th May 1891. on Edison Lalande cells.

These cells used to drive this were of the cautery type †

Res. of field 0.2400 res. of armature 0.2050 Total 0.4450

No. of cells	E MF	Int. res. estimated	Res. of motor	Current Wattes	Current amps	Speed r.p.m.	Counter E.M.F.	Total E.M.F.	Drop in battery	Pd. on motor
1	0.7	0.06	0.4450	.		–		0.495		
2	1.4	0.09		0.4	2.61	280	0	0.535	0.23	1.17
3	2.1	0.130		0.625	3.26	400	0.225	0.575	0.44	1.67
4	2.8	0.170		0.685	3.57	480	0.600	0.615	0.60	2.2
5	3.5	0.210		0.830	4.33	520	0.660	0.655	0.91	2.6
6	4.2	0.25		0.925	4.824	560	0.80	0.795	1.21	3.0

By test on the 13th June, when the first set of coils was mounted, the starting current at 156 volts was 187
By telegram of the 15th the rise of temp. on the coils was 55°5 after several hours.

11th. May 91

Mr. Ballou :-

Kindly note the following winding for the seven sets of [illegible] separating magnets you are now making for Ogden:-

[illegible] - 16 magnets - 28 spools.

Each spool same dimensions as at present but larger flange [illegible] Inner flange 13 ". Internal diameter 5 1/16 [illegible] diameter 6 1/4" Flange diameter 8 1/2

[illegible] 0.18" covered to 0.205" say.

[illegible] lbs. on each spool 225 lbs. on set of 28 spools.

[illegible] will correspond to a length of 718' on each spool

[illegible] inner. 5 3/4 inches.

[illegible] of winding 1.8"

Yours faithfully,

A. E. Kennelly.

Determination of the winding for a series of 16 ore-milling separator = magnets for Ogden N. J. 9th May 91.

The present arrangement is as follows:—

160 volts at dynamo terminals.
155 " " machine terminals.
37 amperes " " " — 4660 Amp. turns per spool — MMF 8372
5735 Watts in machine — 13,320 " " magnet — 16,745
32 spools
179 watts in each spool.

Dimensions of spool:—

			Circumference	
Length	39.5	1.29'		
Interflange	38.25	1.25'		
Int: diam:	13	0.1425'		
Winding	13.3	0.1442'	40.9	1.336'
Over wire	4	2nd layer	47.5	1.54'
		3rd layer	50.3	1.65'

External surface of spool 1836 sq. cms.
Internal " " " 1600 " "

10 sq. cms. per watt of external spool surface per watt.
Wire #8 B.W.G. 0.165" cond. to 0.182". 80 turns per layer = 14.56"-1.21'
Mean circumference 1.5'
Two layers and one quarter 80 turns on the 1st, 80 on the second, 20 on 3rd
180 turns in all = 270' on each spool = 22.6 lbs.
589 lbs: in all and 7150' @ 25¢ = $147.

New design:—

160 volts at dynamo terminals
155 " " machine "
18.5 amperes " "
2867 Watts " "
32 spools
89.6 watts per spool.
4.843 volts " "
0.2618 ohms " " @60°c, 5.378 " in all. @60°c.
360 turns demanded 460 allowed
0.18" covered to 0.195" + 0.21" winding or #7 B.W.G. copper wire.
71 turns per layer
5.75" layers.
1.26" depth of winding.
1.3" over tape.
1.5" between spools.
718' on each spool 23000' in all
70.5 lbs " " 2256 lbs " " @ $0.28 = $519
Diameter of spool over all 0.96', circumference 2.09' 63.7
Internal surface 63.7 × 38.25 = 2437 sq. cms.
27.2 sq. cms. per watt.

Balance between #1 strip in meter #13816

1489w added to whole grid 0.04912

$6525 + 1489 = 8014$

$0.04912 \times \frac{6525}{8014} = 0.039985$

Balance between #2 strip in meter #21214

1425w added to upper half of grid 0.02462w

$6525 + 1425 = 7950$

$0.02462 \times \frac{6525}{7950} = 0.020208w$

Balance between #4 strip in meter #4514

9945w added to upper half of grid

$6525 + 9945 = 16470$

$0.0245 \times \frac{6525}{16470} = 0.009703$?

1544	0.009[illegible]3	−1.7	46.155 46.070	−0.66 −0.[illegible]	1544	0.009[illegible]21	−0.[illegible]	46.070 46.096	−0.24 −0.9
1[illegible]	[illegible]	−1.14	46.110 46.0[illegible]	−0.[illegible] −0.62	1[illegible]9	0.009[illegible]93	−1.03	45.990 46.100	−1.12 0.94
1[illegible]	[illegible]	−0.1[illegible]	46.01 45.[illegible]	−0.93 −1.05	1[illegible]	0.010007	+0.07	45.990 46.030	−1.01 −0.93
1856	0.009466	−1.34	45.90 45.925	−1.08 −[illegible]	1856	0.009[illegible]	−0.0[illegible]	[illegible] [illegible]	−1.15 −1.50
2[illegible]	0.03[illegible]	+0.14	46.1115	−0.65	2[illegible]	0.020011	+0.055	46.225	−0.38
2100	0.01995[illegible]	−0.19	46.387	−0.29	2100	0.02[illegible]	+0.0[illegible]	45.910	−1.19
21[illegible]3	[illegible]	+0.225	46.053	−0.[illegible]	21[illegible]3	0.01946	−3.[illegible]	46.055	+0.75
[illegible]	[illegible]	+0.[illegible]	45.1[illegible]	−1.[illegible]	1253	[illegible]	[illegible]	46.045	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01[illegible]5	−0.15	46.253	−0.65
[illegible]6	[illegible]	[illegible]	[illegible]	[illegible]	1[illegible]6	0.03[illegible]	−0.125	45.070	−2.84
1365	0.0312	−0.45	45.951	−1.1	1365	0.03950	−0.5	45.930	−1.14
1364	0.03165	−0.79	46.004	−0.95	1364	0.03995	−0.24	45.170	−1.03
1367	0.0163	−0.43	45.972	−1.0	1367	0.03[illegible]	−0.5	45.992	−1.0
1434	0.0000	0	45.910	−1.15	1434	0.03985	−0.3	45.930	−1.21
[illegible]	0.0950	−0.5	46.35	−0.24	1343	Total disconnection in April instant.			
[illegible]	[illegible]	−0.15	45.[illegible]	−1.21	1[illegible]15	[illegible]	−0.3	45.9[illegible]	−1.12
12[illegible]	0.2020	+0.5	45.952	−1.1	1375	0.03910	−0.5	45.9[illegible]	−1.[illegible]
[illegible]	[illegible]	−0.124	45.976	−1.23	1354	0.03993	−0.17	45.910	−1.12
1[illegible]	Total disconnection in April instant				1[illegible]14	0.0398[illegible]	−0.3	45.[illegible]	−1.28
	Mean of the disconnecting of [illegible] 0.5[illegible]				Mean of reconnecting of both circuits 1.17				

Fuit Test of Potterville Meters for Edison General Electric Co:

(150)

20 meter cases of the new standard 3-wire type were received for test. of these 4 were $4 ea. 5 were $2.5 and the remaining 11 $1.5. They were tested by differential Galvanometer $\frac{130050}{2}\omega$ in each coil.

No. of Meter	Standard	Value of Standard	Res for Galvanometer	Addition to	Ratio	Inv. Inner of Standard	Res at 17°C.	Res of Meter & stick clock	Lamp & shut	Res of spools	Res of spool & lamp	Temp. air & Bridge	Discrepancy	Speed Rate	Sum
	—	0.00983	0				0.00983	45.419 / 45.3811	0.161	45.278 / 45.221	46.155 / 46.090	TB. 19°C.	-1.7	9.9920 / 9.9918	9.9920 / 9.9918
			60ω	(A)	6.0000 / 6.0525	1.0092	0.009921	45.331 / 45.373		45.193 / 45.211	46.070 / 46.110	Temp. of	-0.79	9.9916 / 9.9918	9.9916 / 9.9918
			37ω	(1)	6.0563 / 6.0525	1.0057	0.009896	45.373 / 45.3805		45.232 / 45.204	46.110 / 46.090	air 15.2°C.	-1.14	9.9920 / 9.9918	9.9920 / 9.9918
			140ω	(2)	6.576 / 6.0525	1.0069	0.009837	45.205 / 45.275		45.264 / 45.244	45.940 / 46.010		-1.02	9.9922 / 9.9922	9.9922 / 9.9922
			100ω	(1)	6.625 / 6.0525	1.0153	0.009781	45.275 / 45.267		45.232 / 45.134	46.010 / 46.01		-0.19	9.9911 / 9.9911	9.9911 / 9.9911
			117ω	(3)	6.642 / 6.0525	1.0180	0.010007	45.257 / 45.297		45.096 / 45.116	45.980 / 46.990		+0.07	9.9979 / 9.9979	9.9979 / 9.9979
			230ω	(1)	6.5514 / 6.0525	1.0036	0.009866	45.225 / 45.195		45.188 / 45.082	46.030 / 45.960		-1.34	9.9972 / 9.9972	9.9972 / 9.9972
			140ω	(2)	6.470 / 6.0525	1.0069	0.009898	45.195 / 44.995		45.082 / 44.857	45.940 / 45.725		-1.02	9.9972 / 9.9972	9.9972 / 9.9972
	—	0.02088	0	0			0.02088	45.418 / 45.418	0.151	45.247	46.165		+0.16	9.9922 / 9.9922	9.9922 / 9.9922
			22ω	(Bat)	(6.547 / 6.0525)''	0.9963	0.02011	45.583 / 45.583		45.227	46.285		+0.055	9.9962 / 9.9962	9.9962 / 9.9962
			39ω	"	6.525 / 6.564	0.9941	0.019962	45.580 / 45.580		45.247	46.327		-0.19	9.9971 / 9.9971	9.9971 / 9.9971
			24ω	"	6.535 / 6.564	0.9961.5	0.020005	45.580 / 45.580		45.039	45.910		+0.025	9.9981 / 9.9981	9.9981 / 9.9981
			7ω	"	6.532 / 6.525	0.99815	0.020046	45.320 / 45.320		45.179	46.053		+0.225	9.9972 / 9.9972	9.9972 / 9.9972
			250ω	"	6.532 / 6.775	0.9631	0.01936	45.320 / 45.110		45.189	46.065		-3.2	9.9915 / 9.9915	9.9915 / 9.9915
			0	"	1	1.0	0.02088	45.110 / 45.110		44.989	45.860		+0.4	9.9971 / 9.9971	9.9971 / 9.9971
			4ω	"	6.525 / 6.529	0.9994	0.020969	45.240 / 45.240		45.139	46.015		+0.325	9.9992 / 9.9992	9.9992 / 9.9992
			34ω	"	6.525 / 6.559	0.9948	0.019972	45.585 / 45.585		45.1389	46.235		-0.025	9.9951 / 9.9951	9.9951 / 9.9951
			31ω	"	6.525 / 6.559	0.9948	0.019972	45.585 / 45.585		45.374	46.253		-0.025	9.9951 / 9.9951	9.9951 / 9.9951
	—	0.039925	0	0			0.03992	45.320 / 45.320	0.161	45.189	46.030		-0.014	9.9997 / 9.9997	9.9997 / 9.9997
			47	Standard	6.525 / 6.572	0.9928	0.03972	45.3250 / 45.3250		45.096	46.070		0.075	9.9916 / 9.9916	9.9916 / 9.9916
			28	"	6.525 / 6.553	0.99525	0.03982	45.240 / 45.240		45.089	45.951		0.45	9.909 / 1.1	9.9916 / 1.1
			43	"	6.525 / 6.568	0.993142	0.03980	45.220 / 45.220		45.039	45.930		0.5	9.9916 / 1.1	9.9916 / 1.1
			56	"	6.525 / 6.581	0.9915	0.03962	45.240 / 45.240		45.129	46.001		0.89	9.9906 / 1.1	9.9906 / 1.1
			0	"	1	1.	0.03998	45.270 / 45.270		45.109	45.980		0.04	9.9907 / 1.1	9.9907 / 1.1
			58	"	6.525 / 6.583	0.9912	0.03963	45.280 / 45.280		45.119	45.992		0.93	9.99 / 1.0	9.99 / 1.0
			28	"	6.525 / 6.553	0.9957	0.03980	45.280 / 45.280		45.119	45.992		0.5	9.99 / 1.0	9.99 / 1.0
			2ω	100	6.625 / 6.625	1.0000	0.040000	45.200 / 45.200		45.139	45.91		0	9.9922 / 1.1	9.9922 / 1.1
			17ω	Standard	(6.625 / 6.625)''	0.9974	0.03988	45.190 / 45.190		45.029	45.90		0.3	9.9979 / 1.1	9.9979 / 1.1
			30ω	"	(6.625 / 6.625)''	0.9954	0.03980	45.063 / 45.063		45.049	46.35		0.5	9.9976 / 1.1	9.9976 / 1.1
			∞	"	dim.	-	-	∞		∞	∞			∞	∞
			7ω	"	(6.625 / 6.625)''	0.9983	0.03994	45.19 / 45.19		45.029	45.90		0.15	9.9979 / 1.1	9.9979 / 1.1
			17ω	"	(6.625 / 6.625)''	0.9974	0.03988	45.225 / 45.225		45.064	45.94		0.3	9.9988 / 1.1	9.9988 / 1.1
			30ω	100	(6.625 / 6.625)''	1.0022	0.04022	45.244 / 45.244		45.079	45.952		0.5	9.989 / 1.1	9.989 / 1.1
			30ω	Standard	(6.625 / 6.625)''	0.9954	0.03980	45.245 / 45.245		45.074	45.948		0.5	9.9989 / 1.1	9.9989 / 1.1
			32ω	"	(6.625 / 6.625)''	0.9948	0.03977	45.415 / 45.415		45.284	46.130		0.6	9.9959 / 1.1	9.9959 / 1.1
			32ω	"	(6.625 / 6.625)''	0.9951	0.03979	45.405 / 45.405		45.244	46.120		0.5	9.9959 / 1.1	9.9959 / 1.1
			26ω	"	(6.625 / 6.625)''	0.9960	0.03985	45.155 / 45.155		45.991	45.870		0.44	9.9972 / 1.1	9.9972 / 1.1
			11ω	"	(6.625 / 6.625)''	0.9983	0.03993	45.225 / 45.225		45.064	45.940		0.15	9.9988 / 1.1	9.9988 / 1.1
			∞	"	dim.			∞		∞					
			15ω	"	(6.625 / 6.625)''	0.9977	0.03989	45.155 / 45.155		44.991	45.865		0.3	9.9972 / 1.1	9.9972 / 1.1

As an important practical example of this calculation, consider the empirical equation of copper conductivity — that for the time we accept as absolutely fine — established by Matthiessen

$$\lambda = 1 + 0.00387 01\, t + 0.00000 9009\, t^2$$

λ being the conductivity at temperature of t°C relative to that at zero C.

Here $b = -3.8701 \times 10^{-3}$ & $c = 9.009 \times 10^{-6}$

Required the best formula of the same species for resistance between the temperatures of 0° + 100°C. ($T = 100$, $t = 0$, $\tau = 50$)

$$P = \frac{-0.003 8701 - 0.000 0009}{1 + 0.193 505 + 0.002 523} = -\frac{0.003 8710}{1.216 028} = -0.006 6664$$

$$\frac{T+t}{2} = \tau = 50$$

$$\frac{T^2 - Tt + t^2}{3} = 3333.\dot{3}$$

$$d = \sqrt{(3.8701^2 \times 10^{-6} - 4 \times 9.009 \times 10^{-6})}$$

$$\sqrt{(14.977 - 36.036)} \times 10^{-3}$$

$$= -4.5891 \times 10^{-3}$$

$$Q = \left[\frac{1}{-4.5891 \times 10^{-3}} \log_e \left\{ \frac{(1.8018 \times 10^{-5} \times 10^{-6} + 3.8701 \times 10^{-3} + 4.5891 \times 10^{-3})(3.8701 \times 10^{-3} - 4.5891 \times 10^{-3})}{(1.8018 \times 10^{-5} \times 10^{-6} + 3.8701 \times 10^{-3} - 4.5891 \times 10^{-3})(3.8701 \times 10^{-3} + 4.5891 \times 10^{-3})} \right\} - 1\right]$$

$$2.1791 \cdot \log_e \left\{ \frac{1.0261 \times 10^{-2}}{1.0829 \times 10^{-3}} \times \frac{-0.7190 \times 10^{-3}}{8.4592 \times 10^{-3}} \right\} - 1$$

Now $4ac > b^2$ so that $Q = \left[\left(\frac{1}{T-t}\right) \frac{2}{\theta} \left\{\tan^{-1} \frac{2cT+b}{e} - \tan^{-1} \frac{2ct+b}{e}\right\} - 1\right] + c \cdot \sqrt{4c-b^2}$

$$e = 4.5891 \times 10^{-3}$$

$$Q = 2 \times 2.1791 \left(\tan^{-1} \frac{1.8018 \times 10^{-3} + 3.8701 \times 10^{-3}}{4.5891 \times 10^{-3}} - \tan^{-1} \frac{3.8701}{4.5891}\right) - 1$$

$$\tan^{-1} \frac{5.6719}{4.5891} - \tan^{-1} \frac{3.8701}{4.5891}$$

$$1.2362 - 0.8433$$

$$51°.2' - 40°.9'$$

$$10°.23'$$

$$4 \times 3582 \times 0.1899 = 0.8278 - 1 = -0.1722$$

$$\begin{vmatrix} q & & \\ 1 & 100 & = +0.0038 9009 \\ 50 & 3333.\dot{3} & = -0.1722 \end{vmatrix} \cdot \Delta = -1666.6$$

$$q = \begin{vmatrix} 0.0038 9009 & 100 \\ 0.1722 & 3333.3 \end{vmatrix} \div -1666.6 = \frac{13.0773 - 17.22}{-1666.6} = \frac{+4.1427}{1666.6}$$

$$r = \begin{vmatrix} 1 & +0.0038 9009 \\ 50 & +0.1722 \end{vmatrix} \div -1666.6 = \frac{+0.1961 6 + 0.1722}{-1666.6} = \frac{+0.0396}{+1666.6}$$

$$q = 2.486 \times 10^{-3}$$

$$r = 1.4377 \times 10^{-5}$$

$$(1 + bt + ct^2 + dt^3)^{-1} = 1 - bt + t^2(b^2 - c) + t^3(2bc - b^3 - d) + t^4(c^2 + 2bd - 3b^2c + b^4) + t^5(2cd - 3b^2d - 3bc^2 + 4b^3c - b^5)$$

With $b = -3.8701 \times 10^{-3}$ and $c = 9.009 \times 10^{-6}$

$$+ 1 + 3.8701 \times 10^{-3} t + 5.968 \times 10^{-6} t^2 - 1.177 \times 10^{-8} t^3 - 9.93 \times 10^{-11} t^4 - 2.79 \times 10^{-13} t^5$$

Having given a certain definite physical relationship expressed by the equation $x = a + bt + ct^2$, and supposing that it is required to find an equation of the same form for the reciprocal of x, determine the best value for the new constants in the equation $\frac{1}{x} = p + qt + rt^2$ in order that the accuracy of the equation may be the greatest possible between certain values Φ and τ of t.

It is always easy to transform these equations into others similar and of the same order but with unity for the first term, so we shall only consider $x = 1 + bt + ct^2$ and $y = \frac{1}{x} = 1 + qt + rt^2$

Let T be a value of t intermediate between Φ and τ and let t be single valued and continuous between these limits.

Then $1 + qt + rt^2 = (1 + bt + ct^2)^{-1}$

Expanding the right hand

$$= 1 - (bt + ct^2) + (bt + ct^2)^2 - (bt + ct^2)^3 + \quad - \&c$$

$$= 1 - bt + t^2(b^2 - c) - t^3(2bc - b^3) + t^4(b^4 - 3b^2c + c^2) + t^5(2bc^2 - 3b^3c + 4b^2c) +$$

The ratio of the 3rd to the fourth term in this expansion is

$$\frac{-\frac{1}{b}(b^2 - c)}{t(b^2 - 2c)}$$

So that unless $\frac{1}{b}$ is large compared with t the subsequent terms cannot be neglected with impunity. We have however

$$d\left\{\frac{1 + qt + rt^2}{dt}\right\} = \frac{d}{dt}\left\{\frac{1}{1 + bt + ct^2}\right\}$$

$$q + 2rt = \frac{-b - 2ct}{(1 + bt + ct^2)^2}$$

$$\therefore r = \left\{\frac{b + 2cT}{(1 + bT + cT^2)^2} - \frac{b + 2ct}{(1 + bt + ct^2)^2}\right\} \frac{1}{2(t - T)}$$

$$q + 2r\tau = \frac{-b - 2c\tau}{(1 + b\tau + c\tau^2)^2} \qquad (1)$$

If τ be $\frac{T+t}{2}$ this relation makes the tangent of the new curve parallel to the tangent of the base curve at the mean value of the independent variable.

Now as a second relation, the area between the respective curves, the terminal ordinates and the abscissa axis are to be equal, we have

$$\int_t^T (1 + qt + rt^2)\, dt = \int_t^T \left(\frac{1}{1 + bt + ct^2}\right) dt$$

$$\text{or } (T - t) + \frac{q}{2}(T^2 - t^2) + \frac{r}{3}(T^3 - t^3) = \frac{1}{d} \log_e \left\{\frac{(2cT + b - d)(2ct + b + d)}{(2cT + b + d)(2ct + b - d)}\right\} \qquad (2)$$

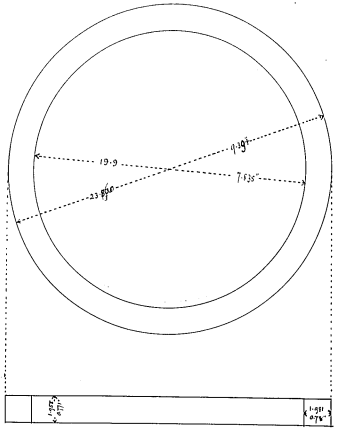
where $d = \sqrt{b^2 - 4c}$

Equations (1) and (2) are theoretically sufficient for the evaluation of q & r

$$\begin{vmatrix} q & r & \\ 1 & 2\tau & = P \\ \frac{(T+t)}{2} & \frac{T^2 + Tt + t^2}{3} & = Q \end{vmatrix} \qquad (3)$$

where $P = \frac{-b - 2c\tau}{(1 + b\tau + c\tau^2)^2}$ & $Q = \left[\frac{1}{d(T-t)} \log_e \left\{\frac{(2cT + b - d)(2ct + b + d)}{(2cT + b + d)(2ct + b - d)}\right\} - 1\right]$

and $d = \sqrt{b^2 - 4c}$



Internal Diameter 19.9 cms
" area 311.026 sq. cms
External Diameter 23.860 cms.
" area 447.1 sq. cms.
Mean diameter 21.88 cms
Annular area 136.07+ sq. cms
Mean circ. 68.74 cms
Mean width 1.958 cms
Mean volume 266.5 c.c.
Mean cross section 3.879 sq. cms.
Mean mass. 1965.9 gms.
Sp. g. mean 7.377

Winding. 2 secondary coils of silk covered wire, each having 20 turns, and situated at opposite points on the ring
1 primary coil of 3 layers 1st layer 324 turns
2nd " 322 "
3rd " 281 "
Total 927.

Test of Sample of Magnetic Steel from The Pennsylvania Steel Co. Steelton Pa. marked no 1.

This casting was an anchor-ring about 1.25" diameter of section. It was turned down in the lathe to a square section, the dimensions being as shown. There were many small blow-holes in the iron ring.

No. of obs.	Source of EMF	EMF	Capacity	a	Mean theor	q per div.	No. of turns
	1 Ld @ 19.5°C	1.4433	2 μ	2.866×10^{-7}	202	1.419×10^{-3}	11

No. of obs.	Steady	Amperes	Amp. turns	MMF	$\frac{H}{MMF}$ (62.74)	No. of turns	Mean theor	Run in cat.	Total nos.	$\frac{q}{(10^{-3})}$	$\mathcal{L}$	ρ		
1.	0.030	0.1564	11.450	1823	26.52	4	3	0	5250.	5.58×10^{-3}	1.44	1.84×10^{-3}		
2.	0.062	0.318	24.48	3706	53.92	6	4.53	0	"	8.427×10^{-3}	2.175	2.78×10^{-3}		
3.	0.072	0.3754	34.80	4374	63.64	4	6.67	0	"	12.42×10^{-3}	3.202	1.987×10^{-3}		
4.	0.085	0.4453	41.28	5189	75.48	4	8.50	0	"	15.83 "	4.081	1.850 "		
5.	0.132	0.688	63.78	8017	116.6	5	13.85	0	"	25.8 "	6.650	1.703 "		
6.	0.182	0.949	87.98	11060	160.9	4	16.95	0	"	31.38 "	8.090	1.99 "		
7.	0.230	1.199	111.15	13814.5	201.14	5	19.5	0	"	36.32 "	9.362	2.15 "		
8.	0.289	1.507	139.7	17556	255.55	4	21.9	0	"	40.4 "	10.415	2.453 "		
9.	0.411	2.143	198.7	22497	326.32	4	16.95	10,000	15,250	1.585 "	11.020	3.075 "		
10	0.630	3.285	304.5	38277	557.68	5	18.6	"	"	57.28 "	13.230	4.210 "		
11	0.850	4.432	411.0	5166	75.16	4	20.3	"	"	52.72 "	14.110	5.328 "		
12	1.205	6.284	582.5	7322	106.5	3	25	"	"	58.15 "	14.990	7.105 "		
13.	1.875	9.776	906.3	11390	165.7	3	22.87	"	"	61.86 "	15.950	10.39 "		

$16 \times 20.5 \times 328 \times 512 = 16800$

$$l = \frac{dcrt}{pc} = \frac{56.4 \times 10^3}{1035 \times 2.48} = \frac{56.4 \times 10^3}{2.142 \times 10^3} = 2.573 \times 10^6 = 2.573\,h.$$

Results of Tests made on the Edison Experimental Alternator at Schenectady May 15th 16th 1891.

The armature is now made up of 0.012" disks separated by sheets of Bristol paper in the usual way. The field is exactly in the condition described in previous data and tests see book III p. 188 and IV 95 & 132. Bore of the fields 24.97".

The first test was without load, (one series of ½ amp. lamps only) and varying field — Started at 14.30

No. of obs.	Rev. of Alternator	Res. in ext.	Multiplier	Reading	Actual effective	Mean EM for increase in effective	Temp. in ends cons	Amp. turns	MMF in ends very est.	Ampere turns equivalent to Res.	Reduction of ext.	Amount in field	Speed of armature r.p.m.	Speed of machine r.p.m.	P.D. in field
1	8750	0	1	136.5	136.5	1.0000 / 2.0000	273	410	1030	1.0000 × 1.0000 = 1.0000 / 1.0000 × 1.0000 = 1.0000	8.07 × 10 = 8.07	1.5	1230	20.5	
2		500	1.814	66.5	122.4	1.0000 / 1.0000		410	1030	1.030 / 1.146	8.99 / 8.99	"			
3		1500	3.61	72.5	261.7	2.000 / 4.000		833	2094	2.500 / 2.448	8.50 / 8.55	3.05			
4		3500	7.09	56.5	400.6	2.000 / 6.000		1365	3431	2.333 / 2.266	10.17 / 9.86	5			
5		"	"	92	652.4	4.000 / 10.000		1911	4803	2.000 / 2.131	9.37 / 9.07	7.0	1220	20.33	
6		6000	11.44	47	537.7	7.000 / 17.000		1775	4461	2.333 / 2.030	7.65 / 8.09	6.5			
7		"	"	65.5	744.4	1.000 / 18.000		2158	6178	1.000 / 1.086	8.61 / 8.82	9			
8		"	"	84	961.2	1.000 / 19.000		3003	7550	1.000 / 1.086	8.33 / 8.40	11			
9		"	"	101.5	1161	1.000 / 20.000		3550	8922	0.917 / 1.086	9.13 / 8.22	13			
10		"	"	112.5	1288	2.000 / 22.000		4076	10200	1.000 / 1.086	8.50 / 8.55	15			9.05
11										5.00	armature	between armature and pole	pole 12200 / 7500		

15.00 Stopped for temperature. Res. of armature 1.7 ω at this temp.

.30 Started again. Temp. on armature by thermometer 60°c. air 26°

.30 113.5 14.0

.52 112.5 14.75

16.30 Stopped again for temperature. Resistance of arm: 2.1 ω.

Calculated rise of temp. by res: $\frac{2.1}{1.7} = 1.2333 = 58.3° = 118.3°$ c. total

.32 Started again.

17.20 Stopped for temp.

.45 Temp. of arm: by thermometer 100°c.

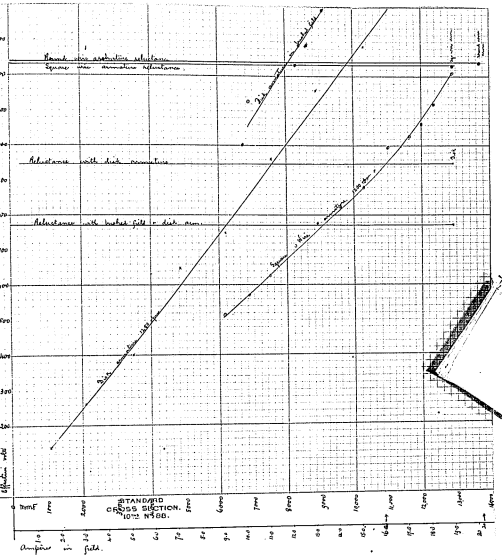
20.0. Started again, and this time on load. Speed 1130 r.p.m.

No. of Obs.	Time	Interval	Res. in Ohms	Multiplier	Reading	Effective E.D.	Amount in field	Amp. turns	MMF	Leads equivalent effective	Amp.	Res. of armature	⅔ Amp.	⅓ Amp.	l calculated
1	20.0		6000	11.435	114.5	1309	14.75	4026	10120	–					
2	.15	0.25	"		101.5	1161	14.2	3877	9750	20.7					
3	.22	0.3	"		101.5	1161	14.2	3877	9750	21.8	100	2ω	43.6	56.4	2.57 h
4	21.00	1.0													

21.00 Stopped for temperature. Res. 1.97 ω Temp. by calculation from this res: 1.165 = 41 + 60 = 101°c. by thermometer 86°c.

Bore 11" × 1.75" × 0.9 = 17.3 sq. in. effective is 111.6 sq. cms.

Big bolt 82 sq. cms.


STANDARD
CROSS SECTION.
No. 1 No. 508.
Amperes in field.
Armature with brushes field + disk num.
Armature with disk commutator
Armature with brushes field
Armature with disk commutator
Armature with brushes field
Armature with disk commutator

Alternator Tests continued –

16th May 91.

A backing of wrought iron plate 0·1" 0·25 m. was next inserted in the field covering the whole width of the magnets. The armature was next revolved in this field and voltages observed –

Obs. No.	Rev. with Cadier	Multiplier	Observed reading	Effective Pd.	Amps in field	MMF 6864	Speed rev. per min. 1200/10	EMF harmonic	Time sec	ρ
1	6000	11·435	88·	1006	9·75	6692	1220 20·3	1423	8.542×10^{5}	7.833×10^{-7}
2			99	1132	10	6864		1601	9.61 "	7·14 "
3			103	1178	10·5	7210		1666	10·0 "	7·21 "
4			108	1235	12	8236		1746	10·48 "	7.86 "
5			112·5	1288	12·25	8407		1821	10·93 "	7·69 "
6			118·5	1390	13·25	9094		1966	11·80 "	7·71 "
7			123·5	1412	13·5	9265		1997	11·99 "	7·73 "
8			129·5	1481	14·2	9746		2094	12·57 "	7·75 "
9			132·5	1515	14·5	9952		2143	12·88 "	7·73 "
10			133·5	1527	14·7	10090		2159	12·96 "	7·78 "
11			112·5	1288	14·5	9952	1210	1821	~~10·93~~	"
12			107·5	1230	12·8	9470	1170	1740		"
13			89	1018	11·2	7690	1000	1440		"
14			83	949	10	8240	990	1342		"
15			98	1121	15	10300	970	1585		"

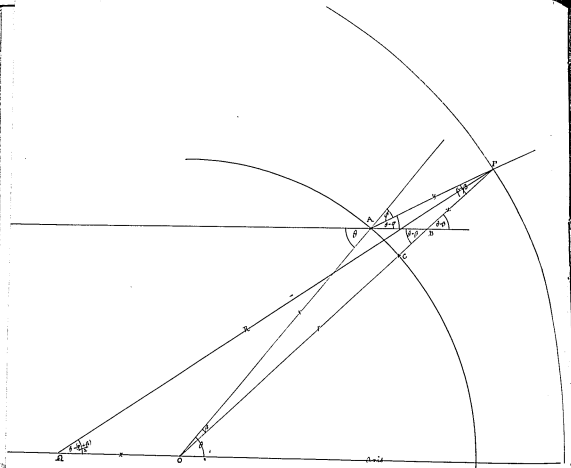
The backing was now removed and the load applied to the machine – Results as follows – Started at 10·0 o'clock.

No.	Potential Cadier	Effective P.D.	EMF harmonic	Rev. with Cadier	Multiplier	Amps in field	Effective load	No. of mins extracts	dens	or	Lc	Speed rev per min	rps	Energy
	63·5	726·2 63·	·	6000	11·435	9	-	20	20			1230	20·5	
2	86	983·4				11·5	-	-	-			-	-	
3	105·5	1206				14·2	-	-	-			-	-	
4	95	1086				12·5	26·5	-				1230	-	
5	94	1075				13·35	33·7	-				-	-	
6	96	1098				13·75	35	-				-	-	
7	94	1075				13·44	34	-	18	68	63 2L·C	-		36·5 kw

Now stopped for temp.

12·30 Temp. on field 49·C.

" " armature 115·5·C.



Let $O\Omega = x$

$OC = OA = r$

$\Omega P = R$

$CP = z$

$AP = y$

Then $\dfrac{x}{r+z} = \dfrac{\sin\left(\frac{\varphi-\beta}{2}\right)}{\sin\left(\theta-\frac{\varphi}{2}-\frac{\varphi}{2}\right)}$

$\dfrac{r+z}{r} = \dfrac{\sin\varphi}{\sin(\theta-\varphi)}$

$\dfrac{r}{r+z} = \dfrac{\sin\theta}{\sin\varphi}$

$\therefore \dfrac{x}{y} = \dfrac{\sin\varphi}{\sin\beta} \cdot \dfrac{\sin\left(\frac{\varphi-\beta}{2}\right)}{\sin\left(\theta-\frac{\varphi}{2}-\frac{\beta}{2}\right)}$

This is the required relation between x and y in order that O may be the focus

But whether O is a focus or not $\dfrac{y}{r} = \dfrac{\sin\beta}{\sin\left(\frac{\varphi-\beta}{2}\right)}$

$\therefore \dfrac{x}{r}$

$\therefore \dfrac{x}{r} = \dfrac{\sin\varphi}{\sin\beta} \cdot \dfrac{\sin\left(\frac{\varphi-\beta}{2}\right)}{\sin\left(\theta-\frac{\varphi}{2}-\frac{\beta}{2}\right)} \cdot \dfrac{\sin\beta}{\sin(\theta-\varphi)}$

$= \dfrac{\sin\varphi}{\sin\left(\theta-\frac{\varphi}{2}-\frac{\beta}{2}\right) \cdot 2\cos\left(\frac{\varphi-\beta}{2}\right)}$ where $\sin\varphi = \mu\sin\theta$

From this equation determine β in terms of θ, x, and r in order that φ may be independent of θ

$\therefore \dfrac{\sin\theta}{\mu}$

$\dfrac{1}{2}\left\{\sin(\theta-\beta) + \sin(\theta-\varphi)\right\} = \dfrac{x}{r}$

" $\dfrac{\sin(\theta-\beta) + \sin(\theta-\varphi)}{\sin\theta} = \dfrac{x}{\mu r}$

Determination of the geometrical relations in a Mangin reflector

A concavo-convex lens of glass of refractive index μ is generated by two eccentric hemispheres of radii r and R. It is required to find what shall be the lengths R and x in order to converge a beam parallel to the axis to a focus at the origin O of $+$ on the axis.

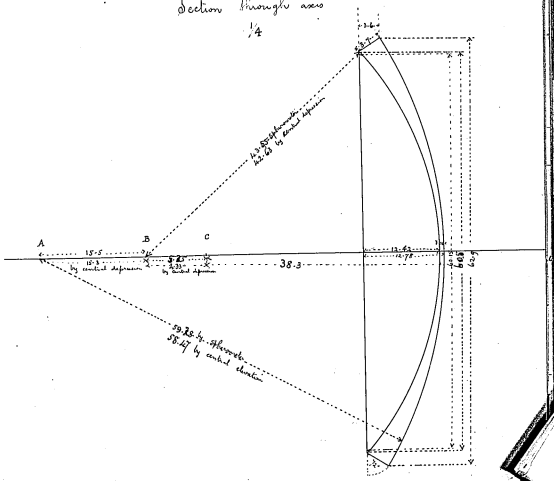
This was the problem as stated by Mr Dobbie.

It appears however from the equations at the foot of the opposite page, in which the right hand side is a constant, that no value of β except $\mu = 1$ + $\beta = \varphi$ will satisfy it. The problem has therefore to be stated afresh under new conditions.

The following are the dimensions of a glass reflector of this kind silvered on the convex surface, and made by Mess. Sautter-Lemonnier.

Section through axis

¼



A is the centre of the external and silvered surface

B . . . . internal - unsilvered -

C . . principal focus

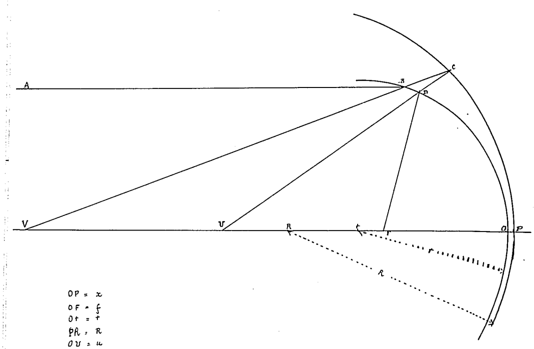
The curvatures appear to be uniform on both faces of the lens.

The external spherometer reading is 4902

. . internal - . . . 5809

. . - zero - . . . 5332

Focus 38·3 from the mirror surface. Weight 30lb.



$OP = x$
$OF = f$
$Or = r$
$PR = R$
$Ov = u$
$OV = v$

The strict formulae are :-

$$\frac{1}{v} = \frac{\mu-1}{\mu}\cdot\frac{1}{r} \qquad (1)$$

$$\frac{1}{v+x} + \frac{1}{u+x} = \frac{2}{R} \qquad (2)$$

$$\frac{\mu}{f} - \frac{1}{u} = \frac{\mu-1}{r} \qquad (3)$$

Since x is a small quantity by comparison, let us write

$$v + x = mv$$
$$u + x = nu$$

Equation (2) then becomes

$$\frac{1}{mv} + \frac{1}{nu} = \frac{2}{R}$$

$$\therefore \frac{1}{u} = \frac{2n}{R} - \frac{n}{m}\cdot\frac{1}{v}$$

$$\therefore \frac{\mu}{f} = \frac{\mu-1}{r} + \frac{2n}{R} - \frac{n}{m}\cdot\frac{1}{v}$$

$$= \frac{\mu-1}{r} + \frac{2n}{R} - \frac{n}{m}\cdot\frac{\mu-1}{\mu}\cdot\frac{1}{r}$$

$$\frac{1}{f} = \frac{\mu-1}{\mu}\cdot\frac{1}{r} + \frac{2n}{\mu}\cdot\frac{1}{R} - \frac{n}{m}\cdot\frac{\mu-1}{\mu^2}\cdot\frac{1}{r}$$

$$\frac{1}{f} = \frac{m\mu R(\mu-1) + 2\mu m n r - nR(\mu-1)}{mRr\mu^2}$$

$$f = \frac{m\mu^2 Rr}{2\mu m n r + R(\mu-1)(m\mu-n)} \qquad (4)$$

And
$$\frac{1}{\mu^2} + \frac{1}{\mu}\left(\frac{2r}{R} - \frac{m+n}{n}\right) = m\left(\frac{nr-f}{fn}\right)$$

or
$$\frac{1}{\mu^2} - \frac{2}{\mu}\left(\frac{m+n}{2n} - \frac{r}{R}\right) = m\left(\frac{nr-f}{fn}\right) \qquad (5)$$

$$\frac{1}{\mu} = \frac{m+n}{2n} - \frac{r}{R} \pm \sqrt{m\left(\frac{nr-f}{fn}\right) + \left(\frac{m+n}{2n} - \frac{r}{R}\right)^2}$$

Reflector Data continued :- In the opposite figure

Let AB be an incident ray parallel to the axis OV. Let it be refracted at incidence along BC, back from C by simple reflection along CD and then refracted to F the principal effective focus of the combination. Let R be the radius of the outer and silvered circle

r - - - - inner - unsilvered.

$OF = f$ be the focal length for parallel rays

$OU = u$ - - equivalent focus of the mirror

$OV = v$ - - - - - of the refracted beam on entering.

μ - the refractive index of the glass with air for the species of light considered.

Then
$$\frac{1}{v} = \frac{\mu-1}{\mu}\cdot\frac{1}{r} \qquad (1)$$

$$\frac{1}{v} + \frac{1}{u} = \frac{2}{R} \qquad (2)$$

$$\frac{\mu}{f} - \frac{1}{u} = \frac{\mu-1}{r} \qquad (3)$$

$$\therefore \frac{1}{v} + \frac{\mu}{f} = \frac{2}{R} + \frac{\mu-1}{r}$$

$$\frac{\mu}{f} = \frac{2}{R} + \frac{1}{r}\left\{\mu-1 - \frac{(\mu-1)}{\mu}\right\}$$

$$\frac{1}{f} = \frac{2}{\mu R} + \frac{\mu-1}{\mu r} - \frac{\mu-1}{\mu^2 r}$$

$$= \frac{2\mu r + \mu(\mu-1)R - (\mu-1)R}{\mu^2 Rr}$$

$$\therefore f = \frac{\mu^2 Rr}{2\mu r + (\mu-1)R\{\mu-1\}}$$

$$= \frac{\mu^2 Rr}{2\mu r + R(\mu-1)^2}$$

When $\mu = 1$ $\therefore f = \frac{R}{2}$

$$\frac{1}{\mu^2} - \frac{2}{\mu}\left(\frac{R-r}{R}\right) = \frac{r-f}{f}$$

$$\left\{\frac{1}{\mu} - \left(\frac{R-r}{R}\right)\right\}^2 = \frac{r-f}{f} + \left(\frac{R-r}{R}\right)^2$$

$$\frac{1}{\mu} = \frac{R-r}{R} \pm \sqrt{\frac{r-f}{f} + \left(\frac{R-r}{R}\right)^2}$$

In the case of the mirror examined $R = 58.47$ $r = 42.63$ $f = 38.3$
from these $\mu = 1.422$.

It is to be observed however that these formulae assume the two circles to coincide at O.

Taking the more accurate formula,

$$\frac{r}{f} = \frac{\mu-1}{\mu} + \frac{2n}{\mu}\frac{r}{R} - \frac{n}{m}\frac{\mu-1}{\mu^2}$$

If $r/f = 1$ this requires

$$\frac{2n}{\mu}\frac{r}{R} = 1 - \frac{\mu-1}{\mu}\left(1 - \frac{n}{m}\frac{1}{\mu}\right)$$

$$\frac{nr}{R} = \frac{\mu}{2} - \frac{\mu-1}{2}\left(1 - \frac{n}{m}\frac{1}{\mu}\right)$$

$$\frac{r+x}{R} = \frac{\mu}{2} - \frac{\mu-1}{2}\left(1 - \frac{n}{m}\frac{1}{\mu}\right) \quad \ldots\ldots\ldots \quad (6)$$

It is best to treat $\frac{n}{m} = 1$ at first and then ascertain the correction

If $\mu = 1.5$
$$\frac{r+x}{R} = \frac{3}{4} - \frac{1}{4}\left(1 - \frac{2}{3}\right)$$

$$= \frac{9}{12} - \frac{1}{12}$$

$$= \frac{8}{12} = \frac{2}{3}$$

Test of the Lift Motor before rewinding it for Battery and Fan work.

Analysis of operation on 110 volt circuit
Turns on armature · 29 × 22 = 638. Wire all round 12 7/6 × 2?
The following observations were made with the machine operated as a dynamo :-

No. of Obs.	Amps in Str. turns	Field amps	Amp turns	MMF	Speed. Rpm.	Rps.	Volts at mt. terminal	φ Webers	B in gap section	Zφ	ρ			
1.	0.3660	0.2741	426	536	3980	66.33	15.5	1.881×10^{-2}	740	2.92×10^{-2}				
2	1.130	0.851	1323	1663	"	"	24.4	3.475 "	1405	4.79×10^{-2}	2.35×10^{-2}			
3	1.2915	0.9724	1511	1899	"	"	29.6	4.218 "	1623	4.732 "	2.36×10^{-2}			
4	0.3839	0.2891	449	564	"	"	11.84	1.398 "	565.8	4.235 "	2.02×10^{-2}			
5	0.1853	0.1395	217	273	"	"	7.90	0.933 "	377.3	2.925 "	1.86×10^{-2}			
6	1.6614 0.395	1.253 1.33	1947	2447	"	"	40.88	4.828 "	1953	5.07 "	2.54×10^{-2}			
7					"	"								

Polar area 4.0 × 6 = 24 sq cms. Pole pitch 5.15 − 4.3 = $\frac{0.85}{2}$ = 0.425
Reluctance $4.25 \times 10^{-4}/24 = 1.75 \times 10^{-2}$

Wound the armature with 14 # 19 B.W.G. wire 0.042" cond. 6 0. " in each section = 154 wires all round. 10 feet in each section = $\frac{110}{10}$ = 27.5 feet equivalent res. = $5.85 \times 2.75 \times 10^{-2} = 0.16\,\omega$ cond. say 0.2 ω warm between brushes.

$0.001617\ (1 + 20 \times 0.00021) = 0.001617\ (1 + 0.0042) = 0.0016238\ \omega$ @ 21°c.

$2722.25 + 6170 = 8892.25$

$\frac{2722.3}{8892.3} \times 0.0016238 = 0.000\,4971\ \omega$ @ 21° c.

$2722.25 + 1730 = 4452.25$

$\frac{2722.3}{4452.3} \times 0.0016238 = 0.000\,99283\ \omega$ @ 21°c.

$2722.25 + 2729 = 5451.3$

$\frac{5451.3}{2722.3} = 2.0023$

$\frac{99283}{49710} = 1.9974$

Test of Standard resistances for the measurement of currents on Underground Feeder.

For the design of these resistances see p. 136.

There are two instruments one with 6 strips, the other with 12.

The strips are 30.35 long 7.62 broad and 0.0203 thick.

The convective surface per strip is 231.3 sq. cms. × 2 = 462.6

" " " for the 6 strip res, is 2775 sq. cm.

" " " " 12 " " = 5550 " "

Measurement of the resistance by comparison with the large shunt on the 23rd May 91.

46 ω added to right hand coil of H.B. galv: for equality.

This included, the resistance = 54444.50 T.B. 21.2° c.

Comparison of 12-plate grid, bippers and large shunt

6170 ω added to shunt Ratio, @ 21° c. 0.000 4971 ω } Corrections see p. 163

Comparison of 6-plate grid and large shunt:-

1730 ω " " shunt. Ratio, @ 21° c. 0.000 99283 ω }

Comparison of 6-plate + 12 plate grid.

2729 ω added to 6 plate. Ratio = 2.0023. Ratio of above results = 1.9974

For ordinary purposes the resistances may be treated as 0.0016 + 0.0005 ω respectively.

The following temperature elevations were observed with these resistances

Obs.	Current	Drop.	Energy Watts	Energy per sq.	Energy per linear cm.	Energy per sq. cm.	Temp.	Elevation	Emission per sq. °C. elevation				
IV 1.	70	0.07	4.9	0.8187	0.02691	0.001531	23.0	2°	0.0017 15				
XII	70	0.035	2.45	0.2062	0.007229	0.000113	23.0	2°	0.00044				
IV 2	95	0.095	9.025	1.502	0.04976	0.00 6304	28	7	0.00093				
XII	95	0.0475	4.510	0.376	0.01239	0.000646	27	6	0.00056				
IV 3	180	0.180	32.4	5.4	0.1779	0.02335	40.5	19.5	0.00117				
XII		0.090	16.2	1.35	0.04448	0.00583	37.5	16.7	0.0003				
VI 4	200	0.200	40.0	6.6	0.2175	0.02855	47°	26°	0.0011				
XII		0.100	20.0	1.65	0.05436	0.007134	38.5	17.5	0.00014				
II 5	220	0.110	24.2	2.085	0.0687	0.009014	48°	27°	0.0003				
					0.06664								
VI 6	310	0.155	48.05	16.0	0.5275	0.0173	55°C	37°	0.0005				
			48.05		0.5275								
VI 7	370	0.185	68.45	7.2	0.1878	0.02465	71°C.	50°	0.00049				
			68.45		0.1878								

Test of a cell brought by Mr Hamilton from Messrs Burnell & Co.

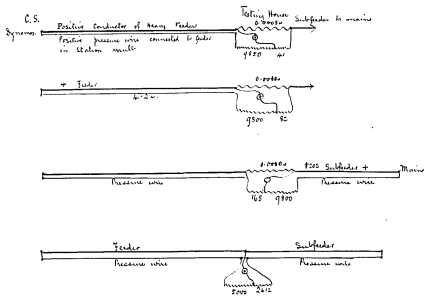
26th May 91.

Cell is contained in a 3 p. case rectangular. It is sealed at the top with paraffine wax through which project two binding posts and a vent tube. The case is stamped Kill's compound

E.M.F. 2.44 volts Int. res: 0.04 ω.

The cell gives on short circuit a current sufficient to fuse a #19 B.W.G. copper wire.

On opening it was found to be a secondary cell using zinc and peroxide of lead as elements. H_2SO_4 solution.



Measurement of the resistance of Brooklyn Feeders 24th May.

The two standard resistances whose tests are recorded on the preceding page were used in these measurements. The connections adopted were those on the opposite page. The long feeder is #1000 and has a length of 9260'. The shorter subfeeder is #500 and is 2240 long. Let r_1 be the resistance of the 0.001 ohm r_2 be the resistance of the 0.0001 ohm. The pressure wires are strands of seven # 15 B.&S. wire 0.057" having each a resistance each of 0.003167 ω per foot, or a joint resistance of $4 \cdot 524 \times 10^{-5}$ ohms per foot. in 9260' a res: of 4·19 ω

The resistance of the long + conductor in the feeder by the 1st test

$= \frac{9854}{41} r_2 = 240.37 r_2$ at temp: of about 20° c.

The resistance of the same conductor by the 2nd test.

$= \frac{9804}{82} r_1 = 119.56 r_1$ at same temperature.

The resistance of the subfeeder by the 3rd test

$= \frac{9802}{165} r_1 = 59.402 r_1$ at same temperature

The ratio of feeder to subfeeder by these 2nd + 3rd tests = 2·013

The ratio . . . . . the 4th test $= \frac{5004}{2412} = 2.079$

The res: per foot of #1000 feeder @ 20° C should be 1.0325×10^{-5} ω

" . . . . . #500 . . . . . 2.065×10^{-5} ω

The pressure wire of the long feeder was connected with the feeder positive in the station vault. That of the subfeeder by copper wire in the junction box with the mains.

The galvanometer was a Thomson minor galvanometer used at first with $\frac{1}{100}$th shunt, and finally unshunted.

The ratio of the two feeder resistances should be $\frac{9260}{2240} = 2.057$

With $r_1 = 0.000993$ the feeder = ~~0.00031~~ 187 ω or 1.282×10^{-5} ω per foot 24·3% high

" subfeeder = 0.05898 ω . 2.633×10^{-5} ω . . 27·5% . .

With $r_1 = 0.000 8523$ the feeder = 0.1019 ω or 1.100×10^{-5} ω per foot 6·6% high

" subfeeder = 0.05064 ω . 2.261×10^{-5} . . . 9·5% .

Speed and pressure of the Lamp: Room Dynamo #10 started 3rd June 91

The belt on the newly set up # 10 dynamo is operated by a new 60" pulley. The belt is 37 feet long and makes 1314·5 passages per minute or 4980' per min. The pulley of the #10 is 13" diam 3.1416' circ = 14.63 r.p.m. At this speed the machine generates 150 amp: with 140·5 volts upstairs and 144 volts at terminal, with about ½ of the resistance box left.

1.00028 @ 16.9 is my standard

1.00028 × 1.00080 = 1.00051 ohm.

17.9 − 15.5 = 2.4 × 3 = 7.2

1.00072

$\frac{2707}{2897} = 96.44$ ∴ 2706.8 + 71 : 9996.4 × 28.07 :: x : 1.0006

$\frac{2807}{100} = 28.07$ 2777.8 : 280600 :: x : 1.0006

$x = \frac{1.0006 \times 2777.8}{280,600} = 0.009902$

2706.8 + 1100 = 3806.8

$\frac{5/6135}{4706.8} = 1.30.2$ 2706.8 : 9311 × 1.8732 :: x : 1.0006

$\frac{76135}{58065} = 1311.$ $x = \frac{1.0006 \times 2706.8}{9311 \times 2.9934} = \frac{1.0006 \times 2706.8}{27944}$

$\frac{2706.8 + 3300}{2000} = \frac{5806.8}{2000} = 2.9034$ = 0.10017

2706.8 + 3315 = 6021.8

$\frac{180654}{9021.5} = 2.0032$ 2706.8 : 9002.2 × 3.00727 :: x : 1.0040

$\frac{2706.8 + 6315}{3000} = \frac{9021.5}{3000} = 3.00727$ $x = \frac{1.0040 \times 2706.8}{9002.2 \times 3.00727} = \frac{1.0040 \times 2706.8}{27070} = 0.10040$

2706.8 + 80 = 2786.8

$\frac{2706.8 \times 1500}{4285.5} = \frac{4159.0}{4285.5} = 1.75.15$ 2706.8 : 9475.1 × 2.8579 :: x : 1.001

$\frac{2786.8 + 1500}{1500} = \frac{4286.8}{1500} = 2.857.9$ $x = \frac{1.001 \times 2706.8}{9475.1 \times 2.8579} = \frac{1.001 \times 2706.8}{27079} = 0.10001$

$\frac{27065}{37068} = 730.8$ 2706.8 + 995 : 9730.8 × 3.706.8 :: x : 1.001

$\frac{2706.8 + 1000}{1000} = 3.7068$ $x = \frac{3601.8 \times 1.001}{3.706.8 \times 9730.8} = \frac{360654}{30097} = 0.009996$

---

19 − 17 = 2 × 0.03 = 0.06

$\frac{21654}{3504.5} = 617.5$ 2706.8 / 1500 } : 9817.5 × 4.3835 :: x : 1.001

$\frac{3504.5}{800} = 4.3835$ $x = \frac{2706.8 \times 1.001}{4.3835 \times 9817.5} = \frac{4301}{43035} = 0.009994$

2706.8 + 195 = 2901.8

$\frac{1500 \times 2901.8}{4401.8} = \frac{43527}{4401.8} = 989$ 2707 + 9489 × 2.9345 :: x : 1.000035

$\frac{2901.8 + 1500}{1500} = \frac{4401.8}{1500} = 2.9345$ $x = \frac{2707 \times 100035}{9489 \times 29345} = \frac{27079}{278455} = 0.0097247$

0.8 0009

$\frac{2707 \times 1000}{3707} = 730.$ 2707 : 9730 × 3.707 :: x : 0.10009

$\frac{2707 + 1000}{1000} = 3.707$ $x = \frac{0.10009 \times 3429}{9730 \times 3707} = \frac{343209}{360691} = 0.0095153$

4097 + 2707 = 6794 $\frac{2707}{6794} \times 0.02462 = 0.009796$

4090 + 2707 = 6797 $\frac{2707}{6797} \times 0.0245 = 0.009756$

$\frac{2707 \times 1000}{4707} = \frac{5407}{4707} = 1.1485$ 2707 / 914 } : 9148.5 × 2.3535 :: x : 0.0098

$\frac{4707}{2000} = 2.3535$ $x = \frac{3626 \times 0.0098}{9148.5 \times 2.3535} = \frac{35532}{2153} = 0.0016506$

$\frac{2707 \times 1500}{4207} = \frac{4060.5}{4207} = 965.2$ 2707 / 914 } : 9465 × 2.8047 :: x : 0.0098

$\frac{4207}{1500} = 2.8047$ = $x = \frac{4426 \times 0.0098}{9465 \times 2.8047} = \frac{43375}{265445} = 0.001634$

Comparison of Standard Resistances 25th May.

(160)

Differential Galvo. H.B. with 1.5ω added to rt.-hand coil.

Res. of both coils 5413.5ω 1000/1000 19°C T.O. = 2706.75ω each coil.

1st Test comparison of two standard ohm coils @ 19.9°C. in water.

1ω added to my standard, a ratio of $\frac{2709.75}{2706.75}$ = 1.0004 it should be 1.0

2nd Test. Comparison of 1/10th Copy, with new Std. 1ω

7½ω added to 1/10th, reduction 9900 : 100

Res. of 1/10th ω @ 18°C. 0.009904 ω.

3rd Test. Comparison of 1/10th Copy with new Std. 1ω.

Bridge reduction 8000 : 2000, and 1150ω inserted

Res. of 1/10th ω @ 18°C. 0.10017ω. = 1.0019 @ 19°C.

4th Test. Repetition of above

Bridge reduction 7000 : 3000, and 3315ω inserted

Res. of 1/10th ω @ 18°C. 0.10010ω = 1.0012 @ 19°C.

5th Test. Repetition of above Temp. of Std. 19°C.

Bridge reduction 8500 : 1500 + 80ω inserted

Res. of 1/10th ω @ 18°C. 0.10007ω = 1.0009 @ 19°C.

6th Test. Repetition of above. Temp. of Std. 19°C.

Bridge reduction 9000 : 1000 + 895ω added to 1/10th

Res. of 1/10th ω @ 19°C. 0.09988ω

7th Test Repetition of above. Temp of Std. 19°C.

Bridge reduction 9200 : 800 + 1590ω added to 1/10th

Res. of 1/10th ω @ 19°C. 0.09994ω.

Mean of all 5 tests ~~0.09999~~ 0.100032ω @ 19°C. or correct @ 17.5°C.

The ratio of the legal to the new ohm is $\frac{105}{106.3}$ = 0.99625 reciprocal 1.0038

a change of 13.3°C. so that this resistance is correct at its new ohm at 30.5°C.

8th Test Comparison of 1/10th with 1/10th @ 19.3°C.

Bridge reduction 8500 : 1500 + 195ω added.

Res. of 1/10th ω @ 19°C. = 0.09972

9th Test Comparison of 1/10th with 1/10th @ 19°C. 1/10th 20.5°C.

Bridge reduction 9000 : 1000. 722ω added to 1/10th

Res. of 1/10th @ 19°C. = 0.09952

10th Comparison of upper lower grid with 0.01ω std. at 23.6°C.

4097ω added to upper grid which by account is 0.02462.

~~4097~~ Res. of 1/10th ω @ 20.6°C. = 0.009796.

4090ω added to lower grid which is 0.0245 by account

~~4090~~ Res. of 1/10th ω @ 20°C. = 0.009756 ω.

11th Comparison of large shunt against 1/10th ω.

Bridge reduction 8000 : 2000 + 919ω added to grid

Res. of large grid 0.001650 @ 20°C.

12th Repetition of above Bridge reduction 8500 : 1500

+ 1719ω added to grid.

Res. of large grid 0.001634 @ 20°C.

2[illegible], 19[illegible]

J. C. Henderson Esq.

Engineer-in-Ch[illegible]

Edison General [illegible] Co.

New York.

Dear Sir :-

I beg to report as follows upon the sample of silicon bronze trolley wire, received here on the 22nd. inst., and accompanying your letter of that date.

Guage # 4 AWG, Mean diameter 0.2590"

Specific gravity 8.88

Weight per foot 0.1722 lb. per mile 911 lbs.

Conductivity 29.8 % of Matthiesson's standard hard drawn copper at temperature of test (20 °C.)

Resistance per foot at 20°C. 0.00004 ohm. per mile 4.38 ohms.

Tensile strength 4200 lbs. weight (no appreciable extension by any stress under 1000 lbs.), or 21,100 lbs. per sq. in.

Ductility 50 twists in twelve inches.

Full particulars of tests can be given on demand.

Yours faithfully,

[illegible]

Consulting Electrician.

Test of a sample of Trolley-Wire (Silicon Bronze) received from the Engineering Department on the 22nd May 91.

The diameter was measured by micrometer as follows.

		Mean "	Mean cms.	Area sq. cms	Area sq: ins	Weight per cm.
1	0.2396					
2	0.2403					
3	0.2394					
4	0.2394					
5	0.2395					
6	0.2394					
7	0.2395					
8	0.2395					
9	0.2395					
10	0.2395	0.2396	0.6086	0.29092	0.04509	~~0.3982~~ 2.569 gms
11	0.2391					
12	0.2394					
13	0.2396					
14	0.2398					
15	0.2397					
16	0.2396					
17	0.2397					
18	0.2398					

Weight per foot	Weight per mile	lbs weight per foot	lbs weight per mile
78.3	413400	0.1727	911.4

Three distances were measured along the wire as follows:-

1st Measurement	2nd Measurement	Mean.
654.6	654.7	654.65
1085.1	1085.2	1085.15
2640.6	2640.8	2640.7

Comparison of the resistances of these lengths with the 0.01 ω. Std.

Length	Res: of Galv.	Std: Res:	Res: added	to	Ratio	Res: of length	res: per cm.	resistivity at temp. of wire abs. units	20°C. Standard Matthiessen Resistivity	% conductivity
~~67.20~~ 640.7	2707	0.0098	6819	trolley	9526	0.03449	2.102 $\times 10^{-5}$	6.115 $\times 10^{3}$	1761	28.8
1085.15	"	-	3592	-	6299	0.022805	2.101 -	6.112 × "	hard drawn 1634 @ 0°	28.8
654.6	-	-	1106	-	3813	0.013805	2.109	6.135 × "		28.8

Comparison with a standard copper bar

Length of rod between file marks	area	Equivalent Length of trolley wire	Equivalent Length of rod 0.2909	% cond: soft copper	Equivalent length of hard rod 0.2909	% cond: hard copper		Res. per ft	Res. per mile
2738	0.3267	71.5	243.8	29.3	238.4	29.99		0.000640	3.381 ω

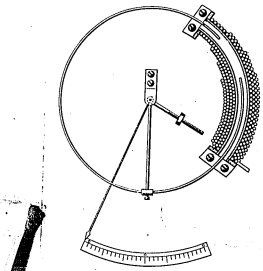
Test for sp. g. Two samples cut off about 5 cms long

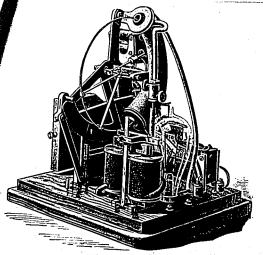
No. 1. in air 14.4045
top H_2O 12.792
loss 1.6125
sp. g. 8.93

No 2. in air 14.0585
" H_2O 12.485
Loss 1.5735
sp. g. 8.932.

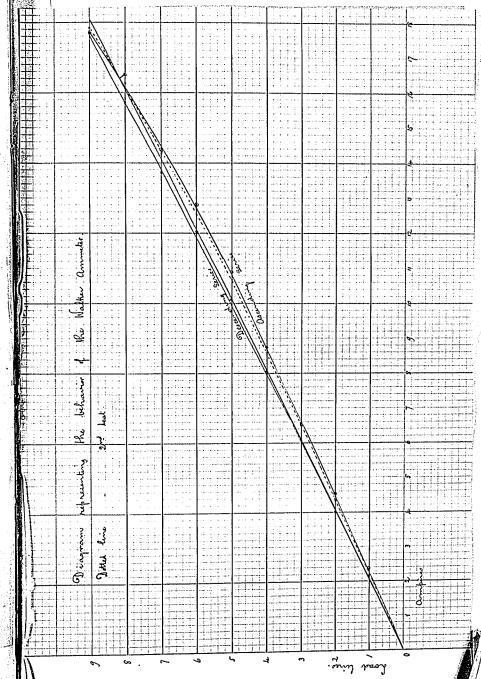
Breaking stress by spring dynamometer —— 1st length 3000 lbs
2nd " 3250
Mean . . . . 3125 lbs.
69.300 lbs. per sq. in., taking 3200 lbs. 70,960 lbs. per sq. in.

Three tests for ductility gave
1, 42 twists in 12" The last is perhaps the
2, 47 " " " most reliable.
3. 50 " " "





RECORDING AMMETER.



Determination of a 500-volt winding for the 1 HP. new Edison Motor 27th May 91.

nd to be 1800 revs. per min at normal flux and light load.
×35 = 140 turns of wire in each groove. The diameter, covered of the
urrent wire is 0.061". The covered diameter of the 500-volt wire can
therefore only be 0.0305"; with 0.018" for covering this is 0.0325" = #25 B&S.
e wire required is # 23 B&S 0.025" cond. 0.037" cov. 8 of these = 0.296":
10.03 × 0.296 = 2.97" wide, 17 high = 0.62".
30 wire with each 0.020" cond. to 0.031" and 14 wire deep = 0.434"

40 turns of # 25 B&S wire 0.020" cond. to 0.030" d.c.c. were wound in a
a sample brass block and found to have a resistance of 2.05 ± 0.02Ω

Test of Walter Meter Scale 28th May 91.

The arrangements of this photographic registering ammeter are shown in the accompanying cuts. To ascertain the degree of accuracy of its indications, a telescope was mounted facing the shutter and about 250 cm away from it. By bringing the cross wire vertical, and then opposite each dead hole in the shutter, the current through the instrument was adjusted until the registering slit was bisected by the same cross wire. The following were the readings obtained which seem to show ~~permanent~~ residual magnetic effect or friction between ascent and descent.

Ascending							Descending					
Clock Deflection	Multiplier	Deflection	Amp/m	Amp/m per hole	Δ amp	No. of Scale line	Clock	Multiple	Deflection	Amp/m	Amp per hole	Δ amp
0.232	2	0.466	2.394	2.394	2.394	1	0.210	2	0.420	2.167	2.167	2.167
0.440		0.880	4.561	2.721	2.147	2	0.388		0.776	4.003	2.002	1.836
0.633		1.266	6.532	2.177	1.991	3	0.590		1.180	6.089	2.030	2.086
0.850		1.700	8.772	2.193	2.240	4	0.780		1.560	8.050	2.013	1.961
1.055		2.110	10.885	2.177	2.113	5	0.978		1.956	10.095	2.019	2.045
1.240		2.480	12.80	2.133	1.915	6	1.160		2.320	11.970	1.962	1.875
1.393		2.786	14.38	2.054	1.580	7	1.320		2.660	13.725	1.961	1.755
1.595		3.190	16.46	2.058	2.08	8	1.520		3.040	15.690	1.961	1.965
1.720		3.440	17.75	1.972	1.29	9	1.720		3.440	17.75	1.972	2.060

The angular range of the pointer is 38°. 12'

6220.
0·4
2658 : 2659 1·4
8878·5 : 2659·4 :: 0·000032 : x

x = 0·029962

2658 5440
0·4 2665 1·4
2665·4 : 8106·2 :: 0·029962 : x x = 0·00785 w

Calibration of Obach Galvanometer after remounting 28th May 91.

The silk fiber having broken, a new one was attached, and about ½ of the brass weight filed off the suspension bar, to reduce the weight on the new fiber. The galvanometer was then adjusted and calibrated by electrolysis as follows:—

Time Secs	Mean Obach reading	Number of Readings	Highest	Weight before	Joint + sum	Weight after	Joint + sum	Gain	Loss	Mean Transfer	Transfer per second (3·285×10⁻⁶)	Ampère	Tons per ampère		
660	+ 0·318	42	0·321 0·315	33·9217 41·7135 75·6352	75·657	34·3775 41·3575 75·735	75·66	0·3558	0·3560	0·3559	5·391×10⁻⁶	1·6405	0·1938		

The area on one side of each plate exposed to the deposit was about 75 sq. cms. allowing about 50 sq. cms. per ampère.

Test of Standard Resistances in terms of 1/10th ohm Copy

28th May

Looped 70 feet of Boston Trolley wire along the floor and measured its resistance between file marks as follows:—

Res: of galv: d.b. H&B. differential with 5 w added to st: hand coil 5385 w @ 17°C. 1000/1000 = 2658 w per coil.

1/10 th w @ 19°C. 6220 w added to 0·1 w.

Resistance of trolley wire 0·029962 w @ 19°C. 2070·5 cms = 1·44471 × 10⁻⁵ w per cm. Also see pages 128 + 129.

Trolley wire against 0·01 w std. 54440 w added to trolley wire.

Resistance of standard 0·01 w 0·009785 w @ 18°C. Platinoid
0·009785 w Legal w @ 0°C.
Correct legal w @ 90°C.

Check — 675·7 cms. equal to the std 0·01 w = 0·009778 w @ 18°C. Platinoid
0·009742 legal w @ 0°C

Large shunt = 112·5 cms. of trolley wire = 0·001628 w @ 18°C. = 0·001622 w 0°C.

6 strip shunt = 58·9 - - - - = 0·000852 3 w @ 18°C. = 0·000848 00

12 - - = 29·5 - - - - = 0·000426 9 w @ 18°C. = 0·000423 00

The best values of the Standards are therefore :—

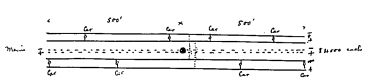
0·1 w. Test on preparation correct 0·1 legal ohm @ 14°C. 28th June 89 p. 79 Book
- - 18th June 89 - - - @ 14°C. - 125 - I
Platinoid - - 25th May 91 - - - @ 17·5°C. most reliable. 149 - III

0·01 w. Mean value before the 28th May 90. 0·009791 @ 0°C see p. 143 Book III
Platinoid Present - - 0·009742 @ 0°C above - 163 - IV.

0·0016 w large gate Measurements 18. XI. 89. p. 135 . I. 0·001627 @ 23·5°C. 143 = 0·001619 Legal w 0°C.
21. X. 90 - 144 - II. 0·001620 @ 22°C - 3 = 0·001613
Platinoid 0·021 ρ. - - - - 0·001626 @ 21·5°C - 1 - 0·001626
28th X 91 - 163 III 0·001628 @ 18°C - 5 - 0·001622
(12) Weighted mean = 0·001619

0·001 6 plate gate given item as above on this page 0·000852 3 @ 18°C = 0·000848 00

0·0005 12 - - - - - - - 0·000426 9 @ 18°C = 0·000423 00



Data concerning new Edison Electrolytic Meter (161)
29th May 91.

For original electrical design see p. 134.
For following are dimensions after completion

Outer glass cell 11.6 ext. 11.1 int. diam: 17.25 high. 2m air.
External zinc cylinder 18.35 ext. high 9.1 ext. 8.5 int. diameter. 900gm
Internal " " 14.35 " " 6.4 " 6.3 " " 120 "
Thickness of outer cylinder wall 0.119". } Dist anos between 1.1
" inner " " 0.025". }

Density of solution 1.11. Both cylinders amalgamated
Res: of cell 17th May 0.215 ω @ 18°C.
" " 29th " 0.250 ω " " " 0.318 ω @ 15.5°C on the 28th May.
Res: of spool 9.646 ω @ 18.8 ω 7.53 ω of 9.3. @ 16°C. { 2.0 ω @ 24°C copper. 2.13 @ 16°C.
This arrangement on 0.4 volt should give a deposit of 5 mgms per ampere hour.

On the cost of copper for a Low-Tension City Street Car System employing a maximum of 20 and a minimum of 15 volts across the metals of the track.

Data Double track, all the conductivity afforded by copper mains. Cars 250 feet apart on each track. Transformers 1000 feet apart. Each car 20,000 lbs: running at 6 mph. up a 3% grade.

Assuming 2 main conductors, and cars at every 125 feet, each transformer feeds four cars up to 500 feet of distance. Gravity = 600 lbs and friction @ 15 lbs: per ton = 150 lbs: Total 750 lbs. 6 mph. = 22 x 6/15 = 8.8 ft per sec. = 6600 ft lbs per sec. = 12 HP. exerted @ 60% gross efficiency = 20 HP. absorbed = 15000 Watts = 1000 amperes at 15 volts or 900 amp. on 17.5 volts the mean pressure.
Load on transformer 3600 amps on each side, carried 250' = 900,000 lb for 5 volts or 2.5 volts in each main = 360,000 conductivity = $4000 copper: or 4 rods each $1000, 8 of such rods in all.
Cost per foot $5.50 of one main = $11 for the roadway) = $58,000 per mile say $65,000 per mile with his plus cost of laying. Probably $75,000 per mile laid.
Each transformer would develop 7200 x 20 = 144 KW. at full load.

Res. of strip in lt. hd. sh. 0.09993 ω 23°C.

" " after . . . 99.71 + 2.5 = 102.21 = 102.25 with shunt

Ratio $\frac{s}{s+s}$ = 0.0009702 = 9.702 × 10^{-4}

For 1224 mpm transformed in the main circuit 1.8720 in the bottle

Res. of strip in rt. hd. sh. 0.09945

after . . . 98.05 + 2.5 = 100.55 = 100.65 with shunt

Ratio $\frac{9.945 \times 10^{-2}}{10.065 \times 10^{2}}$ = 9.882 × 10^{-4}

For 1224 mpm transformed in the main cct. 1.2093 in the bottle

No. of Rule	Mate
1	
2	1st Sec

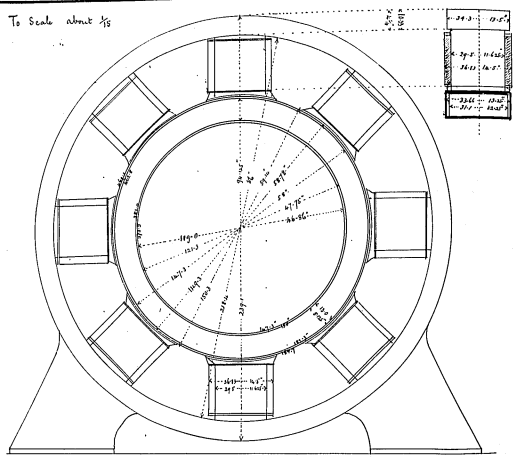
No. of Plate

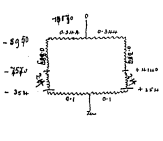
Test of Pottinelle Motors on Loads 12th May

Motor I.C. 47.786 93.586 | 48.2356 | 98.173 | 0.097 | 0.195 | 2.1077 | 0.1110 | 72.56 | (a) 0.0236

No. of Pole	Motor	Measured Weight Pole	Measured Weight armature	Measured Weight Pole	Observed Weight of couple 2.π.91	Couple gain	Gain	Loss	Mean Transfer	Amplitude	Discharge Ratio	Mean Discharge Ratio	Mean ground ratio
1	Standard	49.113 / 47.247	96.362	48.237 / 48.152		96.390	0.0295	0.905	0.876	0.8905	737.7	738.9	(a) 1.0228 1.0165
Left Standard		48.8486 / 48.2497	97.3385	47.227 / 48.239		97.1667	0.0295	0.1919	0.8625	0.8772		736.4	(a) 1.0228
Large Stat.		47.3743 / 48.3065	95.7335	46.765 / 49.020		95.770	0.0265	0.6595	0.6243	0.6419		720.8	(a) 0.9984
1354 rt		46.5064 / 49.9587	96.4770	45.760 / 50.740		96.502	0.025	0.7715	0.7461	0.7590	759	1.029	(a)
1354 lt		49.0670 / 47.7475	96.8166	49.135 / 47.095		96.822	0.026	0.768	0.7	0.7480	759	1.027	(b)
1434 rt		48.9414 / 49.246	98.192	48.2095 / 50.014		98.2165	0.0225	0.769	0.7435	0.7558	755.8	1.0245	(c)
1414 rt		47.9900 / 49.7993	97.781	48.759 / 49.034		97.795	0.014	0.769	0.7533	0.7612	761.2	1.032	(c)
2124 rt		49.678 / 49.831	99.509	49.196 / 50.220		99.416	0.007	0.389	0.382	0.3855	771.0	1.025	(a)
2124 lt		46.286 / 49.9788	93.386	46.671 / 46.739		93.405	0.019	0.388	0.3685	0.3783	756.6	1.0257	(a)
1343 lt		47.2464 / 49.096	96.3625	46.577 / 49.860		96.3765	0.0140	0.764	0.727	0.7455	745.5	1.0105	(b)
1434 lt		46.4852 / 48.5981	95.085	47.261 / 47.824		95.115	0.030	0.7758	0.7444	0.7600	760	1.030	(b)
2123 rt		48.3600 / 46.9380	95.299	48.7438 / 46.5745		95.318	0.019	0.3845	0.3635	0.3735	747	1.0125	(c)
2123 lt		49.4610 / 49.6730	99.1340	49.1014 / 50.072		99.175	0.040	0.399	0.3576	0.3788	757.6	1.0250	(c)
1365 rt		48.5244 / 49.2276	97.8225	47.803 / 50.1020		97.9185	0.026	0.7680	0.741	0.7545	754.5	1.0230	(c)
1365 lt		46.6025 / 48.3695	94.9701	47.376 / 47.622		95.007	0.033	0.7735	0.7375	0.7556	755.5	1.0240	(b)
2100 rt		49.000 / 49.110	98.110	49.385 / 48.729		98.136	0.026	0.385	0.360	0.3728	746.0	1.0144	(a)
2100 lt		49.2480 / 48.785	97.0315	48.787 / 49.176		97.063	0.0315	0.391	0.358	0.3745	749.0	1.0153	(b)
1357 rt		49.1135 / 48.7475	97.863	48.622 / 49.555		97.886	0.023	0.768	0.7315	0.7498	749.8	1.0163	(c)
1357 lt		47.1472 / 50.4724	97.967	46.761 / 51.240		98.001	0.034	0.768	0.7310	0.7495	749.5	1.0160	(c)
1363 lt		49.259 / 48.139	97.701	48.8985 / 48.8510		97.722	0.021	0.387	0.3625	0.3758	749.6	1.0162	(b)
1386 rt		46.6550 / 47.7613	96.4412	48.916 / 50.228		96.3565	0.0245	0.759	0.734	0.7465	746.5	1.012	(a)
1363 rt		48.6825 / 47.4175	95.7035	49.083 / 46.674		95.757	0.0335	0.3945	0.363	0.3815	763	1.0342	(b)
1386 lt		47.259 / 48.9214	96.2114	48.822 / 46.207		96.229	0.015	0.763	0.747	0.755	755	1.0233	(a)
2122 rt		47.2055 / 50.7490	96.1245	48.6400 / 50.553		96.154	0.0265	0.3915	0.366	0.3788	757.6	1.0270	(a)
2122 lt		48.985 / 48.206	97.193	48.6461 / 48.593		97.217	0.024	0.387	0.361	0.374	748	1.0140	(b)
1415 rt		48.555 / 48.268	93.8234	47.822 / 46.035		93.8365	0.0125	0.767	0.753	0.760	760	1.0220	(a)
1415 lt		47.511 / 48.975	96.487	48.280 / 48.233		96.513	0.026	0.769	0.742	0.756	756	1.0242	(a)
456 rt		48.4466 / 48.9815	96.8295	48.6425 / 47.997		96.850	0.0205	0.1965	0.1745	0.1855	742	1.0058	(a)
456 lt		46.5100 / 49.4732	95.9832	46.5763 / 49.498		96.002	0.0185	0.0145 / 0.0155	×	–			
1364 r		46.288 / 49.2614	95.5505	48.5493 / 50.032		98.582	0.0275	0.768	0.7385	0.7538	753.3	1.0210	(a)
1364 l		47.281 / 49.1419	96.700	48.803 / 48.6765		96.745	0.0195	0.762	0.7325	0.7473	747.3	1.013	(b)
1469 r		48.940 / 48.331	97.272	49.134 / 48.160		97.295	0.023	0.194	0.171	0.1825	730	0.9895	(a)
1469 l		48.922 / 47.8265	96.309	49.077 / 47.516		96.3325	0.0235	0.195	0.1705	0.1828	731.2	0.991	(a)
1347 r		49.195 / 49.222	98.418	48.11574 / 49.9825		98.4415	0.0245	0.7645	0.741	0.7538	753.8	1.022	(b)
1347 l		50.687 / 48.8255	96.5143	50.1057 / 46.116		96.568	0.025	0.766	0.729	0.7525	752.5	1.020	(a)
1477 rt		48.667 / 49.561	98.2285	48.846 / 49.390		98.255	0.0165	0.199	0.171	0.1850	740	1.003 / 1.0050	(a)
1477 lt		48.3985 / 48.0485	96.4465	48.2235 / 48.223		96.445	0.0205	0.1955	0.1705	0.1805	742	1.0058	(a)
1375 r		48.723 / 47.195	95.923	47.9925 / 47.923		95.9252	1.029	0.768	0.7385	0.7533	753.3	1.0211	(b)
1375 l		48.234 / 47.156	95.391	49.0105 / 46.4030		95.419	0.027	0.7765	0.748	0.7623	762.3	1.0332	(b)
1456 r		47.971 / 47.371	95.3425	48.6265 / 47.1265		95.2725	0.030	0.1955	0.1655	0.1805	721.2	0.9775	(a)

To Scale about 1/15





Circuit reluctance

armature	0.2
Air	2.28
Core	0.78
Keeper	0.67
	5.45

$5.45 \times 3.538 \times 10^3 = 21{,}050$ = 168140 ampere turns
= 84020 on each spool.

The polar PD across the air gap is $5000 \times 1.5 = 7500$
- armature PD. (superior limit) is $\frac{1}{0.8} \times 48 \times \frac{683}{8} = 5124$

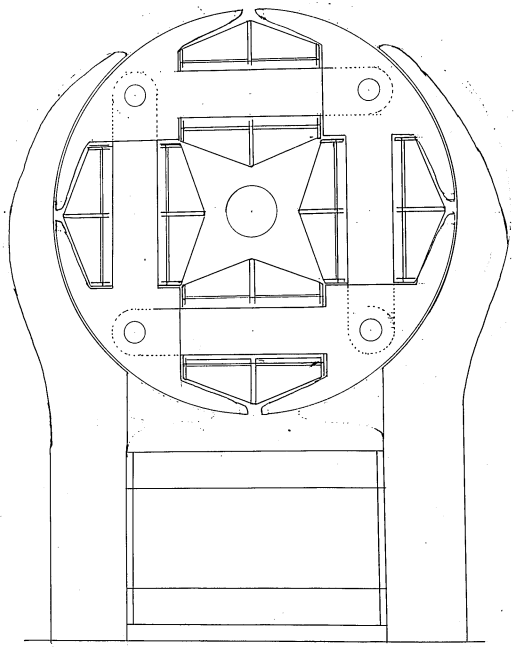
In the formula $W = \frac{2Bl}{\pi s}$,
$s = 1.5$.

Data of the new Octopolar 100 KW. Direct Driven Dynamo as proposed by Schenectady Works 30th May 91.

(166)

Octopolar gramme ring. Cast steel field. Disk armature.
172 r/pm = 28.6 r.p.s. Peripheral speed 1342 kmr = 528.3" = 44.0' p.sec.
Turns on armature 768 — 96 per segment
Current density (7t per cm² of armt. cir.) 140.
Section of bar 60,000 sq. mil.
Intensity in air gap 5000.
Flux 3.538×10^4 in armature or 7.075×10^4 usefully through each pole.
E.M.F generated 155.9 volts.
Breadth of armature body 13.5" 34.3 } Mean diam 114.3 cms Mean cir. 422
Radial depth - - - 5.0625' 12.87 } Gross section of body 1424.1 sq. cms
Volume of armature 186,100 c.c.
Section of short iron disks 372 sq. cm. reduction factor 0.8144
Mean density in armt. at full flux 9500.
Diameter of core 11.625' 29.5 cast steel. Sectional area 683.5 106 sq. in.
Section of keeper 13.5" × 4.0625" = 54.85 sq. in. 34.3 × 10.33 = 354.2 sq. cms.
Length of one turn on armature 3.05'
Total length on armature 23142'.
Resistance of armature hot $\frac{10.145 \times 23142}{68{,}900 \times 144} = \frac{2.1425 \times 10^{-3}}{3.24 \times 10^6} = 6.37 \times 10^{-3} = 0.00637\,\Omega$ @ 100°C
Full load current 670 + 13 = 683 amp.
Drop in armature at full load = 4.33 volts
Power lost - - - - = 2960 Watts.
Temperature of armature = 60°C at full load
Resistance of armature = $\frac{9.276 \times 23142}{68{,}900 \times 144} = \frac{2.173 \times 10^{-3}}{3.24 \times 10^6} = 5.659\,\mu\Omega \times 10^{-3} = 0.00566 = @ 60°C$
Drop in armature @ 60°C. under full load = 3.87 volts
Power lost - - - - - - - = 2640 Watts.
Watts per sq. in. of radiating surface 2640/4713 = 85.85
- - - cm. - - - - 0.085 Watts.
Ampere turns on each core at full load 7600
Current in shunt field 12.66).
Res. of field hot 9.58 Ω
Watts per sq. in. on field 0.28 per sq. cm. 0.0434 = 23.0 sq. cm. per Watt.
Estimated rise of temp. on field 22.4°C.
Total weight of copper on field 904 lbs. # 10 B&S.
Watts lost in field 1670, in res. box. 225 . = 132 volts in field, 15 in box.
Polar angle 31° aac 41 cms. Area 41 × 34 = 1394 sq. cms exp 1100
Entifer 4.5 cms. Entifer reluctance 17/1100 = 1.07 millihenrys.
Armature reluctance 50 cms length 1372 at a density of 9500 and
reluctivity 1.4 ml. = 70/372 = 0.19 ml. say 0.2 ml.
Calling the magnetic potential at the centre of the armature segment zero,
the potential of the armature underneath the pole is $0.1 \times 3.538 \times 10^3 = 352.8$
- - - - pole surface - - $1.17 \times 3.538 \times 10^3 = 4140$
Reluctance of core 40 cms. /342 , at B = 13,750 μ = 3.3 ml. = 0.324 ml. × μ.
- - - 76 - /354 at B = 13,270 μ = 3.2 - = 0.687 -

The density in the core will be about 14,600.
Increasing the area 7% gives 731.4 sq. cm. = 30.5 cm. = 12" diameter.
There are 600 turns of wire on each core
Increasing the area 18% gives 754 sq. cm = 31 cms = 12.21"
Half an inch more depth in the keeper would mean 95 × 13.5 × 3.142 × 0.3 = 1242
The keeper was subsequently increased to 4 7/16".
Hysteresis in armature 1255 Watts.



40

2·1

2·12

40

Determination of the Electromagnetic circuits for a fan motor to operate at 120 volts pressure

The revolutions per minute to be 1100. = 18·3 per sec.

" ~~open~~ voltage of the armature to be 40.

" number of wire all round = $\frac{9 \times 10^{8}}{1{\cdot}68 \times 10^{6} \times 1{\cdot}933 \times 10^{6}} = \frac{9 \times 10^{8}}{1{\cdot}68 \times 10^{6}} = 5000$

" cross section of wire = 2·440 sq. cm. in armature.

useful flux = 16,000 × 2·4 × 2 = 76,800

turns per bobbin will be 500% = 625

winding space section in each half bobbin did 2·3 × 0·9 = 2·07 sq. cm.

" " " " " " 0·92 × 0·350 = 0·322 " in

" " per wire = 0·322 ÷ 625 = $5{\cdot}5 \times 10^{-4}$ sq. in. = $7{\cdot}365 \times 10^{-2}$ diam.

= 0·023" s.c.c. to 0·016". # 27 B.W.G.

The cross-section of the field magnet should be 50 sq. cm.

diameter " " " " " 3·6 cm.

" " " " " " 1·42".

Mean winding diameter 1·75" circ. = 5·5" = 0·458'.

Total length of wire 2290' ~~x 0·0~~ $7{\cdot}755 \times 10^{-4} \times 2{\cdot}29 \times 10^{3}$ = 1·78 lbs.

resistance " $2{\cdot}29 \times 10^{3} \times 4{\cdot}612 \times 10^{-2}$ = 13·38 × 10 = 133·8 ω ÷ 4 = 33·4 ω

Reluctance of air gap with 0·1 entefer = $\frac{0{\cdot}2}{18{\cdot}5 \times 15}$ = 0·01, and to force 76,800 lines through this will take 768 × 0·8 = 614 at. AT or 0·7 amp 9·80 turns

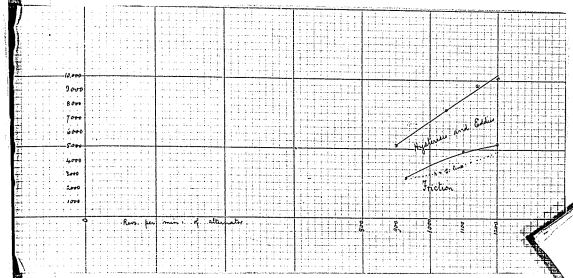
There are 11 c. in. of coiling space on the magnet = 2 lbs; and the res. of the coil hot = 4·0 ω = 20 ω per lb. = 26 B.W.G. 0·022" s.c.c. to 0·029

The mean turns = 0·5' there will be 110 turns and 17 layers = 1870 turns = 935'. 2·44 × 9·35 = 22·8 ω

With # 25 B.W.G. 0·020" s.c.c. to 0·027" there will be 125 turns and 18 layers = 2250 turns = 1125' × 0·02952 = 33·2 ω.

With # 26 B.W.G. 0·018" s.c.c. to 0·025" there will be 136 turns and 20 layers = 2720 turns = 1360' × 0·03645 = 49·6 ω. Say 40 ω of this wire

2720 × $\frac{4}{5}$ = 2176 turns and 16·32 gti = about 1·1 lb. wire


10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Rev. per min. of alternator
Induction and Eddy
Hysteresis
Friction

Experiments with the Alternator.

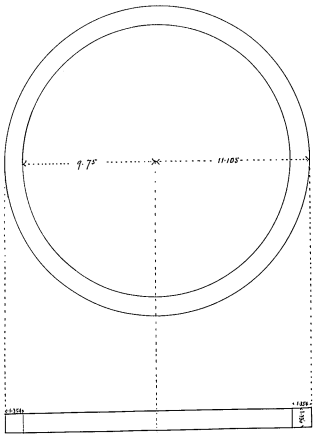
The machine was operated on the 4th June by the #12 machine to it acting as a motor and the other #12 as a dynamo driven by the engine. With the brushes full and 12 ℓ of excitation, the motor absorbed 90 amps @ 98 volts = 8820 Watts running at 1000 rpm and generating about 1100 volts effective.

Took following power readings

Volts across m.t.	Current thro motor	Energy in motor	Energy absorbed above motor [illegible]	Speed of Alternator	Current in Alternator field	Current in alternator	Energy absorb in alternator at p.f. = 0.25		
100	11	1100	0	0	0	0			
104	40	4160	3060	932	0	0	2906		
126	50	6300	5200	1100	0	0	4940		
135	50	6750	5650	1200	0	0	5368		
101.5	65	6598	5498	900	1.67	0	5223		
125	75	9375	8275	1050	"	0	7860		
127.5	80	10200	9100	1020	-	0	8644		
140	80	11200	10100	1140	-	0	9594		
144	81.5	11736	10636	1200	-	0	10,100		

On 5th June operated the 100 l. Edison Transformer successfully, lighting up 12 lamps of 16 cp (at pds between 50 & 75 volts). The transformer gave a rather loud sound. It attained a temperature of 75° C. after running for two hours.

Plan and Diametrical section of Ring no 1. Scale ½.



Internal radius	9.75	Diameter	19.5	Circ.	61.26
External -	11.105	-	22.21	-	69.78
Mean -	10.4275	-	20.855	-	65.52

External area	387.42	
Internal -	298.65	
Annular -	88.77	
Depth of ring	1.336	(0.526")
Breadth " "	1.354	(0.533")
Cross section - -	1.809	
Volume - -	118.6 c.c.	
Weight in air	920 gms	919.5 gm by stone room scale
- - Imputed	803 -	@ 17°C.
Volume	117 c.c.	by weighing

sp. g. 7.864

An indentation at one place on the edge amounting to 0.13 would reduce the cross section locally by 0.009 so that the cross section may be assumed at 1.8 sq. cm

Two opposite secondary windings each 50 turns. silk covered platinoid.

Primary 1st	336	583		
2nd	337			
3rd	342			
Outside	16	337	986	

Total

$$\frac{1.257 \times 980}{65.52} = 18.81 = H \text{ per amp: with all primary in cct.}$$

Particulars of Magnetic Test Rings received from Stratton Pa.

(169)

8 rings were received from Stratton on the afternoon of the 4th June. They were welded from bars of different composition, and marked 1 to 8. They were very irregular in sections and were therefore turned up to a rectangular section in the lathe.

The analyses of the metal in these rings were received in a letter from Stratton dated the 5th June

	C.	Ph.	Mn.	Si.	S.	
Bar # 1	0.13	0.008	0.31	0.01	0.029	For effect of Ph.
2	0.13	0.038	0.39	0.01	0.05	
" 3	0.33	0.013	0.46	0.01	0.026	For effect of Ph + Mn
" 4	0.28	0.114	1.12	0.02	0.043	
" 5	0.15	0.018	0.53	0.01	0.013	For effect of C.
" 6	1.08	0.007	0.19	0.01	0.013	
" 7	0.39	0.088	0.77	0.04	0.047	For effect of Si.
" 8	0.44	0.037	0.82	0.26	0.032	

Test of # 1 Ring

No. of Obs.	Source of EMF	EMF	Capacity	a	Mean Thickness	q per div	
	1.6.6.10 19.8°C	1.4325×10^{-8}	2.9×10^{-15}	2.865×10^{-7}	211.2	1.356×10^{-3}	

No. of Obs.	Ext.	Obsch	Amp.	H	No. of Turns	Mean Thick	Res in cels.	Res of cct.	$q \times 10^{-8}$	q	L	H	μ	$\rho \times 10^{-3}$
1	0.09991		0.0752	1.417	5	19.9	0	0.250	2.698	14.16	787	1.417	555.5	1.80
2	0.13165		0.09926	1.867	5	43.4	0	-	5.885	30.90	1717	1.867	919.6	1.087
3	0.20305		0.15316	2.885	5	120.3	0	-	17.67	92.78	5155	2.885	1787.	55.976
4	0.40423		0.3162	5.947	5	265.1	0	-	35.94	188.60	10,480	5.947	1762	25.675
5	0.59247	0.088	0.44723 / 0.42534	8.474	5	553.4	25,000	30,250	7.242	21.90	12,170	8.474	1436	0.6966
6		0.099	0.515	9.687	4	93.9	12,500	17,750	12.73	22.590	12,550	9.687	1295	0.7722
7		1.2325	1.205	22.67	5	112.8	-	-	15.30	27.150	15,080	22.67	663.2	1.503
8		0.452	2.333	43.89	4	120.6	-	-	16.35	29.020	16,120	43.89	367.14	2.722
9		1.68	8.668	81.630	5	139.4	-	-	18.90	33.540	18.630	81.630	184.2	8.756

On the design of a machine for solving simultaneous linear equations, and determinants

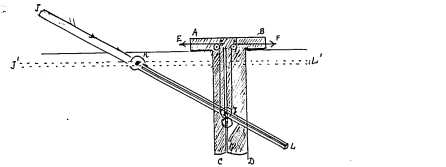
7th June 91.

Sir W. Thomson has given in an Appendix to Thomson & Tait's Natural Philosophy a description of a very ingenious machine for the same purpose. It seems probable however that if the principle here to be described, and which operates on a different principle will work at all, it will be simpler and more accurate than Thomson's.

A metal grid is used for each equation. If there are four simultaneous equations or 4 unknowns, there will be four grids in use, although a machine may be arranged for any number of unknowns and have any number of grids without requiring any change for the use of a lesser number.

Each grid has as many parallel slots as there are grids in the machine. Frames slides and are definitely clamped in these slots, ~~two~~ one in each, ~~one for positive and the other for negative values of the~~. Each frame AB has two strong uprights CD separated by a space in which slides with working fit, the ends of a movable pulley I. A cord EF preferably a thin strong and inelastic wire runs over this loose pulley and the fixed pulleys G & H. The position of this pulley I in the groove is determined by a guide rod KL pivoted at K, where zero is horizontal J'L'. A strutty parallel guide rod on the same axis runs in each slot of the grid.

To operate the machine, all the grids are fixed in line. Cords or wires are then run through each set of 3 pulleys in each grid, one wire for each ~~grid~~ slot, so that if there be 6 grids, there will be 6 wires each in its corresponding line of slots. The wires are secured at ~~the~~ one end, at the extremity of the last grid. The frames AB are now set to scale in their grooves at the coefficient of their representative unknown on the right of K if +, to the left if −, with the guide rods all horizontal. The wires are now pulled taut and brought to a zero point on the edge of the 1st grid. Lengths of wire equal to the absolute terms in each equation are measured off to scale and fed in if + or prepared for hauling out if −. All the feeds are then clamped. The guide rods have now to be manipulated until the slack in the wire entirely disappears. This must be done by trial. A persistently slack wire has to be tightened by hauling over the guides in the grid of its high coefficients and wice versa. The operation could be performed unerringly and immediately with two grids and two wires, with a little more delay for 3 grids and wires, and probably more and more delay with each additional equation and unknown, but perhaps the operation would always be successful. When attained the rods would be clamped, and the tangents of the angles from zero described by each rod would be the value of each corresponding unknown.



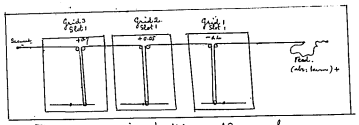


Diagram representing one end in position with levers at zero, frames clamped, and ready for feed.

There are 2 wires parallel, only one shown.

$b = a \tan\theta$

If $\tan\theta = x$

$b = ax$